Employer
SAKO BRNO A.S.

Project
High-efficient combined heat and power facility utilizing renewable sources (OHB II - line K1)

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PART III, APPENDIX A3
TECHNICAL SPECIFICATIONS FOR FLUE GAS TREATMENT SYSTEM

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Ramboll
Hannemanns Allé 53
DK-2300 Copenhagen S
Denmark

T +45 5161 1000
F +45 5161 1001
www.ramboll.com/energy

Rambøll Danmark A/S
DK reg.no. 35128417

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1. GENERAL

1.1 Concept

1.1.1 BASIS

The Contract Object shall include a complete, independent, fully functional and corrosion proof flue gas cleaning system to treat the flue gas coming from the boiler for particles, Hg and other heavy metals, HCl, HF, SO_2, dioxins and furans. The same reagents shall be used as for the Existing facility's flue gas treatments.

The entire flue gas treatment system except the stack shall be contained in the building envelope to minimize the propagation of noise and dust.

The bag house filter system shall be able to fulfil the required air emissions as stand-alone system without help from a down-stream flue gas condensation system (Option 1).

Reference is made to the diagrams of the proposed concept in appendix A15 *Concept Diagrams for Process*.

The expected volumetric flow rate, temperature, pressure and composition of the flue gas to be treated are stated together with other process and design data in appendix A13 *Process and Design Data*, and the treatment requirements expressed as emission limit values are stated toge-ther with guarantee values in Part II.h *Guarantees*. Compliance with the emission limit values shall be guaranteed. The system must be capable to handle peaks in flue gas composition, especially with respect to SO2 peaks. The contractor shall describe the intended method to handle high concentration of pollutants and especially quick changes. The procedure for guarantee test is described in appendix A20 *Procedure for Guarantee tests*.

The proposed concept shall be optimised with particular attention to the evaluation criteria of the evaluation guidelines.

The Contract Object shall include the following main components:

- Inlet duct arrangement including measurements
- Quencher / reactor
- Baghouse filter
- Reagent handling
- Recirculation of reagent / residue
- Residue handling
- Induced draught fan (ID-fan), including silencer
- Automated Continuous Emission Measurement Station (CEMS)
- All duct work
- Necessary modifications of the existing stack

In addition, the Contract Object shall include all necessary auxiliary equipment such as necessary blowers and compressors, storage silos and tanks.

As a part of the basis scope the FGT system shall be prepared for later establishment of Option 1 (Low Temperature ECO and Flue Gas Condensation).

Consequently, e.g. the ID fan design shall be based on the inclusion of this additional equipment, ducts shall be sufficient for the increased under-pressure and the stack flue shall be able to withstand the potential flue gas composition and properties related to the options, e.g. flue gas condensation.

1.1.2 OPTION: LOW-TEMPERATURE ECONOMIZER AND FLUE GAS CONDENSATION

A low-temperature economizer and flue gas condensation shall be offered as an option. Refer to option 1 described in appendix A21 *Options*.

Option 1 includes the design, manufacture, supply, erection, testing, commissioning and documentation of the following:

- Low temperature economizer (LT ECO)
- Flue gas condenser and absorption heat pump
- Droplet fall-out mitigation (e.g. flue gas re-heater)
- Condensate water treatment system
- All necessary connections to the DH system for heat transfer
- All necessary auxiliary equipment including heat exchangers, circulation pumps, pipes, valves
- All necessary modifications to the Scope of Contract Object (including but not limited to ID fan, ducts and stack pipe) as a result of this option

The low temperature economizer and flue gas condenser shall be located downstream the bag-house filter and upstream the ID-fan.

The condensate shall, to the extent possible, be treated and reused within the Complete Plant or treated to fulfil requirements for boiler water/district heating water quality in order to offer the Employer an alternative usage of the condensate.

The surplus condensate which cannot be reused shall be transferred to the Employer's existing IBA wastewater pit after treatment. The treatment system shall produce a water quality that is acceptable for the receiver.

1.2 Overall Design and Layout Requirements

In the design and layout general attention shall be paid to:

- The flue gas path shall be gas tight with particular emphasis on avoiding the escape of corrosive gases and the intake of ambient air.
- Liquid process streams shall be contained in closed pipe systems. This also applies to all overflow and emptying lines of scrubbers and tanks into agreed canals, sumps and collection trenches for reuse.
- Trenches and sumps for emergency use and periodic cleaning with water shall be included.
- Open trenches and pits/sumps shall be used only for emergencies and for the periodic cleaning with water.
- Pits and sumps shall be equipped with necessary agitators to hinder undesired sedimentation.
- Pumping of the media streams from pits and sumps are included in the supply.
- Liquid collected in sumps in the FGT-part of the building shall be used in the FGT process. Any such liquid shall be filtered before it is returned to the process to avoid any clogging by foreign matter.

- Process design and layout shall be chosen to minimise the risk of leakage of corrosive liquids, and minimise the damage in case of leaks, including risk of exposure to operating staff. In case of corrosive content, tanks shall be placed in a room where health and safety risks and damage/corrosion caused by leaks are minimised to the greatest extent possible. The layout and routes of pipes shall ensure that these risks are minimised in case of leaks from pipes, pumps etc.
- Process design and layout shall be chosen to minimise the risk of leak of corrosive gases and minimise the damage in the case of leaks. Tanks, vessels and sumps shall be designed so that fumes do not escape to the room from the tanks, they shall be ventilated and the off-gas treated prior to discharge. In case of corrosive content, tanks shall be placed in a room where health and safety risks and damage/corrosion caused by leaks are minimised to the greatest extent possible.
- The operators' contact with hot surfaces shall be avoided primarily by thermal insulation for the purpose of avoiding burns and limiting the heat loss, refer to appendix A14.4 *Insulation and Cladding for Process*.
- Manual handling of chemicals shall be avoided.
- All dampers and valves shall also be enabled to be operated manually.
- Constructions in glass fibre shall be designed and dimensioned according to the specifications of appendix A14.11 *Fibre-Reinforced Plastic (FRP) and Plastic Welds*.
- An investigation by computational fluid dynamics (CFD) shall be conducted to verify appropriate flow and temperature distribution in critical components of the FGT system, *e.g.* the duct upstream the CEMS as described in appendix C1 *Reviewable Project and Design Data*.
- All stairs, ladders and platforms necessary for access to equipment, conducting measurements, taking samples and maintenance shall be included.

1.3 Measurements

The Contractor shall equip the Line with the measurements and sampling ports necessary for the safe and reliable operation of the Line, and according to requirements of the Authorities.

All silos and other storage systems (for solids or powdery materials) shall be equipped with weighing cells and limit switches.

All tanks (for liquid products) shall be equipped with analogues level measurements and limit switches.

The mass flows of all consumables and products (chemicals, water, compressed air, steam, etc.) shall be measured with high accuracy. Please refer to chapter 7.1.1 for accuracy of measurements. In the case of several, significant consumers, measurements shall be established for each consumer.

Trace-heated surfaces shall be temperature controlled.

Differential pressure shall be measured over all components that may experience blocking or fouling such as the reactor-loop, bag house filter, the individual packed beds in scrubber-system and demisters.

For the purpose of determining Line performance, it must be possible to take samples of all consumables and residues, and of all process streams flowing between the main components described in main sections of this appendix. This includes the necessary openings, sampling ports or sampling stations for flue gas, liquid or solid streams. All sampling stations shall be equipped with safety devices, such as ventilation to ensure that the operator is not exposed to fumes, and likewise.

Heat production from heat pumps shall be determined continuously, e.g. by measurement of temperatures and flows of all ingoing and outgoing streams and energy consumption of all relevant consumers, e.g. electrical power consumption of compressor, etc.

A minimum extent of measurements is shown in Table 1 for reference, with exception of the Continuous Emission Monitoring System (CEMS) which is specified in section 5.2.

Table 1, Minimum Extent of Measurements.

Position of the measurement point		Scope of Contract Object: B=Base O=Option [(1)]	Medium	Parameter P = Pressure T = Temperature F = Flow E = Energy D = Density C = Conductivity S = Speed V = Vibrations
Main component upstream	Main component downstream			
Boiler Economizer	Quencher/ reactor	B	Flue gas	T P H_2O SO_2 HCl NH_3 CO NO_x O_2 See footnote [(2)]
Quench/reactor	Bag house filter	B	Flue gas	T P
Bag house filter	Downstream process	B	Flue gas	T P
Bag house filter	Downstream process (only relevant for Option 1)	O	Flue gas	Dust HCl SO_2
Quenches	Circulation flows	O	Scrubber water	F
Flue gas condenser	Circulation flows	O	Condensate	F, T
Quencher/Condenser	Condensate/Bleed tank	O	Condensate/Bleed	F
Condensate/Bleed tank	Furnace Reactor	O	Condensate/Bleed etc.	F
Clean condensate tank	Make-up water and other purposes within Line	O	Pretreated condensate	F, C
Fresh water supply	Process water tank	B	Water	F
Water supply	Condensate buffer tank	O	Water	F
Water supply	Hydrator	B	Water	F
Water supply	Reactor	B	Water	F
Water supply	Emergency water-tank	B	Water	F
Water supply	Demister after flue gas condenser	O	Water	F
$Ca(OH)_2$- or CaO silo	Reactor	B	$Ca(OH)_2$ or CaO	F (mass)
Activated Carbon silo/storage system	Reactor	B	AC or HOK	F (mass)
Bag house filter	Reactor	B	Recirculated residue	F (mass)

NaOH-tank	Flue gas condenser	O	NaOH solution	F
Upstream process	ID-fan	B	Flue gas	T P
ID-fan	Emission Measurement System	B	Flue gas	P T
ID-fan	-	B	Rotor	E (shaft power) S
ID-fan	-	B	Bearing	V T
ID-fan	-	B	Motor	V T
Compressed air	Total usage of different users	B	Air	F P
Fluidising air heater	Before and after each preheating stage.	B	Air	T T
Fluidizing component	Pressure Flow (each section)			P F
(1) The scope specified with abbreviation "O" is to be included with the related process technical option, e.g. Condensing scrubber. (2) Reference is also made to Part III, Appendix A2, Chapter 17.2 Measurement of Flue Gas Concentrations				

2. REACTOR AND BAG HOUSE FILTER

A quench/reactor for cooling of the flue gas and reaction with absorbents and adsorbents shall be installed. The reactor design margin shall cover all transients, overloads and variations. Downstream the reactor, the cooled and partially reacted flue gas enters the bag house filters where acid gases, particulates, heavy metals, dioxins and furans are removed through filtration.

The system shall allow individual adjustment of the amount of lime (absorbent) and activated carbon (adsorbents).

The resulting residual product shall be transported to the silo for residual products. Part of the residue may be re-injected into the flue gas to improve the utilisation of the reagents.

2.1 Raw Gas Measurements

Raw gas measurements before the reactor/bag house filter unit shall be suitable for the task. In-situ measurements are preferred. An increased amount of dust and humidity must be taken into account. Concentrations, flue gas velocities and temperatures shall be evened out before the measurements. Therefor special care shall be taken designing the inlet duct.

The dosing controls for the reagents (lime and other) and water injection shall utilize the raw gas measurement signals (feed forward).

Access and maintenance to the raw gas measurements shall be easy. For this reason, galleries and platforms shall be installed to provide easy access.

The make and type of the instruments shall be coordinated with that of the Continuous Emission Monitoring System (CEMS). It is anticipated the Sub-contractor of the raw gas measurements and the CEMS is identical.

Any necessary calibration gas station, with bottle fixation equipment and gas connection systems is included in the supply.

A certain number of spare nozzles/flanges shall be included in the raw gas measuring duct section which might be advisable for 3rd party and calibration measurements as well as for setting additional instruments.

2.2 Quencher/Reactor

In the quencher/reactor the flue gas is cooled by evaporation of water.

Fresh adsorbents, absorbents and other reagents from bag house filter shall be injected into the flue gas.

Recirculated residue from the bag house filter shall also be injected in the flue gas stream upstream the baghouse filter or into the reactor to improve reagent utilisation.

The injection system shall be designed in such a way that the reagents and residuals are evenly distributed over the complete cross section of the flue gas duct.

The injection zone and the water injection/evaporation shall be designed and constructed in such a way that deposits and accumulation of material are avoided, and all water is evaporated completely in the flue gas before reaching any of the reactor or duct walls. Therefore, special care has to be taken, to assure generation of evenly fine defined droplets and controlled dispersion and evaporation of droplets inside the flue gas path at all times.

It shall be possible to detect accumulation of material in the bottom of the reactor and reactor loop if the system is designed with such.

2.3 Bag House Filter

The reactor/bag house filter system shall be equipped, designed and dimensioned so that all environmental requirements can be met downstream the bag house filter, i.e. upstream low temperature economizer (Option 1).

The bag house filter shall be subdivided in sections. The filter shall be able to treat 100% of the nominal flue gas flow with one module or minimum 10 % of the filter modules out of service for e.g. maintenance, replacement of damaged bags etc.

It shall be possible to isolate a module during operation, enabling maintenance work to be conducted on one module while the flue gas treatment system operates at full load. Appropriate dampers shall be installed in order to safely allow personnel access to the out-of-service module.

Filter bag material shall be chosen for high chemical resistance and temperature not to be damaged by the temperature occurring under the most adverse conditions, including max. boiler outlet temperature and failure of water injection system occurring simultaneously.

Downstream the baghouse filter and upstream the next flue gas component, e.g. low temperature economiser (Option 1) a dust monitoring system shall be included in order to detect and automatically identify damaged bags. Alternatively, the dust signal of the CEMS might be utilized.

The bag house filter shall be designed without an external or an internal bypass. All necessary precautions shall be made to allow start-up and shut-down without by-passing the bag house filter.

It shall be possible to install and remove bags in one piece without bending from the clean side through a walk-in plenum. A service platform with a minimum width of 2.5 meter shall be included to provide access to the walk-in plenum. The platform shall be provided with sufficient room to facilitate bag and cage removal and replacement. Access doors through the building roof are not acceptable.

The filter shall be equipped with commercially available bags of a material adapted to the actual conditions, including most adverse conditions.

The bag house filter shall be a reverse-air, pulse jet cleaned. Purging the bags shall be automatic with air pulses when triggered, e.g. in a sequence controlled by the pressure drop across the filter. The purge sequence shall ensure as far as possible a minimum of "pollutant peaks" in the clean gas.

The residue extraction system shall be designed to eliminate the risk of bridge-building, and bottom collectors shall be emptied automatically and continuously. If a bottom sluice fails to operate, the appertaining filter section shall be taken out of operation for service. The residue extraction system shall be surveyed for possible blocking during operation. Inspection hatches shall be included to facilitate service and maintenance of the extraction system.

The filter and the bottom collectors shall be equipped with the necessary electrical heating elements to keep the filter warm during shutdowns and to preheat the filter before start-up of the incineration line. In addition, all necessary precautions shall be taken to prevent corrosion, formation of deposits, lumps and bridging. For instance, the filter cages shall be made of corrosion proof material in heavy duty construction, e.g. duplex steel, AISI 316 or similar.

The inside of the filter house shall be completely coated with appropriate material in order to prevent corrosion.

The filter shall be furnished with the necessary level guards.

In addition, the filter shall be furnished with all necessary equipment to prevent fire and explosion as well as with all necessary stairs, ladders and platforms.

An emergency system for emptying residue from bag house filter to big bags shall be included.

Equipment for pre-coating shall be included. It is unacceptable to use $Ca(OH)_2$ made directly from CaO for pre-coating, unless good references can be provided. If CaO is used as absorbent, the process of preparing $Ca(OH)_2$ for pre-coating of the bag house filter shall be described. All lines for feeding of material for precoating shall be permanently installed pipes.

The Sub-contractor shall describe how the filter bags, filter casing and hoppers residue extraction system are protected during longer and shorter periods of shutdown.

The Sub-contractor is asked to evaluate the overall advantages and disadvantages of a separate pressurised air system for the bag house filter in case that the quality requirement is considerably lower than the quality of instrument air.

2.4 Transport Systems for Absorbent (lime) and Adsorbent (activated carbon)

The absorbent and adsorbent shall be transported pneumatically from the storage systems to the reactor. The Employer has preference for a robust system that can be serviced during operation.

Equipment for receiving absorbent and absorbent underneath the storage system, dosing and transport to the reactor are included in the scope of supply.

2.5 Lime injection

A complete dosing system for lime shall be included in the supply.

The lime injection system shall consist of a dosage device feeding to a pneumatic transport and injection system including a dedicated air supply (blower with noise attenuator).

The lime injection system shall be connected to the injection nozzle by pneumatic pipes/hoses.

It shall be possible to remove clogging and plugs by compressed air and mechanically. The pneumatic transport equipment shall contain measurements to monitor and control any increased pressure loss. Failure to generate flow and dosing must be detected. Pneumatic removal of plugs or other clogging shall be automatically controlled.

The system shall be completely sealed and leak-free.

2.6 Activated carbon injection

A complete dosing system for active carbon shall be included in the supply.

The activated carbon injection system shall consist of a dosage device feeding to a pneumatic transport and injection system including a dedicated air supply (blower with noise attenuator).

The activated carbon injection system shall be connected to the injection nozzle by pneumatic pipes/hoses.

It shall be possible to remove clogging and plugs by compressed air and mechanically. The pneumatic transport equipment shall contain measurements to monitor and control any increased pressure loss. Failure to generate flow and dosing must be detected. Pneumatic removal of plugs or other clogging shall be automatically controlled.

The system shall be completely sealed and leak-free.

2.7 Device for Re-injection of Used Absorbent/Adsorbents

Part of the used absorbent/adsorbent is expected to be re-injected into the flue gas to improve the utilisation of the reagents.

From the bag house filter the used absorbent/adsorbent enters a distribution silo or similar in which the used absorbent/adsorbent is split up in a fraction to be re-injected and a fraction to be transported to the residual product silo.

In addition, the device for re-injection shall include all equipment needed for storing, transporting, re-injecting and otherwise handling the residual product emanating from the bag house filter, including silos and conveyors etc.

The rate of re-injected absorbent/adsorbent shall be adjustable and measured.

All equipment in contact with the used absorbent/adsorbent shall be insulated and electrically heat traced.

2.8 Handling of Residue

The remaining residual product from the bag house filter and from the bottom of the reactor shall be transported in an insulated and electrically heat traced pneumatic transport system to the ash and residual product silo (provided by the employer). The system is described in section 7.4 Silo for Residual Products.

The end product silo contains:

- residue from bag house filter
- residue from bottom of reactor
- boiler ash

In case of a pneumatic transport system boiler ash and residue from bottom of reactor shall be crushed in a designated crusher prior to sending to the residue silo in order to prevent transport problems. Screw conveyor, rotary feeder or similar are not accepted as crushing devices.

Pressure vessels for transport shall be designed with easy access for manual cleaning of the inside of the vessel. Insulation of the pressure vessels shall be easy to dismantle and to re-install.

Pipes with increased material thicknesses shall be used. Special precautions shall be taken to prevent leakages, especially in elbows/bends.

In addition, the handling system shall include all equipment needed for storing, transporting and otherwise handling the residual product emanating from the bag house filter, including necessary intermediate buffer silos and conveyors etc.

It shall be possible during operation to remove objects from the bottom of the reactor or from the bag house filter extraction system that are too large for the crushers. The objects shall be transferred to a mobile container without manual interference.

3. LOW-TEMPERATURE ECONOMIZER AND FLUE GAS CONDENSATION (OPTION)

For optimizing the total energy recovery from the Line, a low-temperature economizer and a flue gas condensation system shall be offered as an option.

The option includes the design, manufacture, supply, erection, testing, commissioning and documentation of the following:

- Low temperature economizer (LT ECO)
- Flue gas condenser and absorption heat pump
- Droplet fallout mitigation (e.g. flue gas re-heater)
- Condensate water treatment system
- All necessary connections to the DH system for heat transfer
- All necessary auxiliary equipment including heat exchangers, circulation pumps, pipes, valves
- All necessary modifications to the Scope of Contract Object (including but not limited to ID fan, ducts and stack pipe) as a result of this option

Reference is made to option 1 in appendix A21 *Options*.

This section describes the technical specifications for the equipment to be delivered under this option.

3.1 General

The flue gas cleaning system shall include facilities for heat recovery and condensing the water vapour in the flue gas. The main purpose of this equipment is to recover heat for use in the district heating system by cooling the flue gas and condensing the water vapour contained in the flue gas through heat exchange with district-heating water/heat pump.

As a consequence, condensate is generated, which shall be reused in the Line to the greatest possible extent, e.g. for the semi-dry flue gas treatment section, for cooling of incineration bottom ash, for preparation of boiler make-up water or likewise. Discharge of the process wastewater from the Line shall be minimized.

This entails that freshwater consumptions shall be minimized, e.g. by optimizing droplet eliminator flushing cycles.

Condensate, which cannot be reused inside the Line, shall be reused in the Existing facility or finally discharged to the public sewer upon the Employer's acceptance fulfilling all Authorities regulations.

The flue gas cleaning plant shall operate flawlessly complying with all specifications and guarantees given both with and without the condensing process in operation.

The heat recovery system shall generate district heating, increasing the overall thermal efficiency of the Line.

The preferred main configuration of the equipment is seen in Appendix A15 *Concepts Diagrams for Process*.

As a first step for heat recovery a "dry" District Heating Economizer or Low Temperature ECO (LT ECO) shall be installed after the Baghouse filter. In a second step the condensing shall take place downstream the LT ECO.

The heat recovery from the condensing process shall be based on heat exchange with heat pump technology.

The flue gas condensate system shall be tight against leakages from and to the district-heating water.

The condensation system shall be optimised towards high heat output considering the available DH water flow upstream the turbine condenser(s).

It shall be possible to control the energy output after given set-points for the heat output and condensate production.

In operation it shall be possible to fully control the flue gas condensation step and thereby the production of excess condensate by adjusting the amount of recovered energy.

The number of process steps downstream the ID-fan shall be limited to reduce the risk of escaping flue gas caused by overpressure in the flue gas path.

The required capacities of the system are specified in Appendix A13, Process and Design Data.

3.2 Low Temperature ECO

The Low Temperature ECO (LT ECO) shall serve as heat recovery downstream the baghouse filter.

The flue gas temperature shall be decreased to reduce evaporation in the following condenser system.

The energy shall be transferred to district heating water, which acts as cooling media. The Contractor may alternatively suggest the heat transferred to the boiler circuit via usage in e.g. the air-preheaters.

Corrosion protection of tubes and casing shall be designed with due respect to the operational conditions, i.e. the full range of water inlet temperatures. In low temperature parts as a minimum the economiser tubes shall be corrosion protected by use of coating by enamel and the fluoropolymer PFA, and the casing protected by use of PFA. The Contractor may alternatively propose duplex stainless steel or other less durable materials. In this case the Contractor shall evaluate the investment saving against increased operational costs for exchange or repair. Special care shall be taken when designing the heat exchanger considering thermal expansions of tubes and shell and the cleaning method to safely avoid cracking of material and coating and premature degradation of the equipment. Dust, dirt and clogging may not lead to increased mechanical stress or decay. If alternative materials and coatings are suggested the Sub-contractor shall provide prove of better chemical resistivity and superior properties with respect to the mechanical aspects against the cracking, abrasion and erosion.

The design of the heat exchanger tubes supports frequent fluctuation of operation conditions. Precautions must be taken to compensate movements due to thermal expansion and stress of especially tubes and protective sheeting.

The design and dimensioning of the heat transfer surface area must take the media compositions into account. This includes the setting of sufficient fouling factors.

The system shall be capable of controlling the flue gas outlet temperature to an operator selected setpoint.

On the liquid side the system shall contain a closed pressurised loop including a controlled shunting system with pumps, valves and a water / water heat exchanger for connection to the DH system. Boiling up / steam formation must be safely avoided inside the system and on the DH water side. The flue gas outlet temperature and thereby the heat transfer is regulated by increasing or throttling the shunt water flow.

The operation of the economiser shall be adjustable, so the operator can choose the extent of energy recovery (including shutting it off e.g. in periods where the District Heating consumption is low), and the design of the economiser system shall have no technical limitations of this pattern of operation.

3.3 Flue Gas Condenser

The condenser shall cool the flue gas to the saturation point and condense the humidity by subcooling. Flue gas shall be evenly distributed over the cross sections of the condenser.

The sub-cooled stream shall be circulated via a heat pump.

All circulation streams shall be equipped with frequency-controlled pumps.

Condensate shall be neutralised by NaOH.

A set of effective state of the art mist eliminators shall ensure low carry-over of droplets to the downstream flue gas duct and ID-fan.

The outlet flue gas temperature shall be measured with high accuracy, and the duct shall be equipped with a number of stubs designed order to measure the cross-section profiles of flow, temperature and droplet content in the duct as spot measurements.

On the condensate side the heat production shall be measured via the in- and outgoing flows and temperatures.

3.4 Emergency Cooling/Temperature Durability

To prevent high temperatures after the LT ECO from damaging the downstream equipment either the equipment must be fit for the maximal temperatures arriving from the LT ECO or a safe emergency system shall be installed.

Then, the system shall be furnished with an elevated water tank or similar with sufficient capacity to ensure cooling of the equipment during shut down e.g. during power blackout. Dedicated injection nozzles shall be used for emergency water.

For dimensioning of emergency water system, the most adverse combination of conditions shall be assumed, including LT ECO out of operation, no external power supply and lack of water supplies.

3.5 Heat Pump System

The heat pump system is a common system in its entity and the chilled water shall be connected to the flue gas condenser in a chilled water circuit (included). Main components in the system are the heat pump unit, heat exchanger in between condensation units and a chilled circuit.

The Employer expects that the chilled circuit will be cooled to around 30-35 °C.

It shall be possible to isolate the heat exchanger so that service and dismantling will be possible with the flue gas treatment still in operation.

The Contractor shall base the design on the heat pump system on an absorption heat pump where the driving heat source is medium pressure steam delivered from the existing extraction turbine of Existing facility.

The limit of supply towards the Employer regarding MP extraction steam from Existing facility and condensate return to Existing facility is included in appendix A18 *Limits of Supply.*
The properties of MP extraction steam available from Existing facility and the requirements to condensate returned to Existing facility are presented in appendix A13 *Process and Design Data.*

The Contractor shall include a description and heat and mass balances of the heat pump system in his tender proposal. Refer to appendix 0.g *Forms for Technical Data*.

3.6 Droplet fallout mitigation

Droplet fallout from the flue gas shall be avoided.

The Contractor may for this purpose chose to install a reheater that ensures that the flue gas is heated well above the dew point.

The heat source is either steam from the turbine bleed, DH water or water from the intermediate cycle of the LT ECO.

The reheater shall be designed or selected in such a way that:

- Condensation of humidity in the subsequent systems, e.g. ducts and stack are avoided
- Protection against droplet fall out in and around the stack is mitigated. The minimum temperature increase is stated in Appendix A13 *Process and Design Data*.
- It is protected against corrosion by a method which has proven its viability for such applications
- It is kept clean from deposits of any kind
- The heating surfaces – or the entire reheater – can be easily replaced, and single tubes shall be easy to block
- Preferably the flue gas passes outside horizontal tubes with heat transfer media inside the tubes
- It can be taken out of operation while the flue gas treatment Line is in operation with no adverse effects on the operation of the Line.

Special care shall be taken that temperature and flow gradients over the cross section of the duct are avoided to ensure proper measurement of the CEMS.

3.7 Treatment of Condensate

The condensate from the flue gas condenser shall as a minimum pass a particle filter and collected in a condensate buffer tank if necessary.

The condensate shall, to the extent possible, be treated and reused within the Complete plant to minimize the use of fresh water.

The surplus condensate which cannot be reused shall be transferred to the Employer's existing IBA wastewater pit after treatment. The treatment system shall produce a water quality that is acceptable for the receiver.

For the condensate treatment and reuse of condensate the following priorities shall be met:

1) Internal usage in FGT systems of Line and Existing facility
2) Pre-treatment for makeup water Line for boiler / district heating to offer the Employer an alternative for usage.
3) Discharge to Employer's existing IBA wastewater pit

The Contractor shall propose a treatment method for the condensate.

Relevant parameters shall be measured for surveillance and control.

4. INDUCED DRAUGHT FAN

The flue gas cleaning Line shall be equipped with an induced draught fan (ID-fan) to overcome the pressure loss of the flue gas system in the incinerator/boiler, flue gas cleaning system and stack. The fan ensures at all times negative pressure in the furnace and flue gas path to prevent flue gases escaping into the boiler hall. It shall be designed to properly ventilate the boiler and to counteract accumulation of unburnt explosive flue gases inside the boiler chamber, other parts of the flue gas path or the boiler hall. Consequently, the ID-fan is part of the boiler safety circuit.

The position of the fan and the silencer in the process sequence shall be proposed with due respect to:

- Keeping the required negative pressure in furnace at all times
- Limiting the presence of overpressure in the flue gas path
- Limiting the power consumption
- Limiting noise emission via ducts and stack

The ID-fan shall be located in the "cold" position, i.e. location downstream the condensing section and upstream the re-heater. Duct and fan condensates shall be led to a suitable receiver tank and returned to the flue gas treatment process.

In connection with the dimensioning, consideration to all operating situations shall be taken so that corrosion and fouling etc. do not occur.

The fan shall be centrifugal and be equipped with one or two frequency-controlled motors. At least one of the motors must be connected to the electrical emergency power system.

Power transfer via belt is not acceptable.

ID-fan and motor capacities are to be satisfied as a minimum according to Appendix A13 *Process and Design Data*.

In case of black out the emergency power system must synchronize with the ID-fan motor drive unit on the fly by to operate with emergency capacity. In case of failure to synchronize the motor must be able to start from stand still at reduced power.

The fan and motors shall be equipped with vibration and temperature measurements on the bearings and the signals must be transferred to the CMS. Necessary instrumentation for boiler protection (SIL-classified) shall be included.

It shall be possible to replace fan impeller without dismounting ducts, compensators or dampers. The impeller must not be welded on the shaft.

Bottom frames, vibration absorbers and noise reduction including ventilated noise reduction hoods shall be included in the Contract Object.

Silencers in the flue gas path shall be included in the supply. The silencers shall be made of corrosion resistant material. It shall be possible to replace baffles individually. Any duct condensate shall be collected and returned to the process via a suitable tank/pit.

Reference is made to Appendix A14.3 *Acoustic Noise and Vibrations*, where amongst other the potential use of noise hoods is described.

5. FLUE GAS MEASUREMENTS

5.1 Raw Gas Monitoring

The Line shall comprise continuous raw gas measurements upstream the reactor/bag house filter according to specification in Section 1.3. The measured data shall be available as actual reading as well as in standard units in the CMS system.

The make and types of the raw gas instrumentation shall be coordinated with the make and types for the emission monitoring instrumentation. The intention is to satisfy the priorities of the Employer to hold flue gas monitoring instrumentation of the same quality and serviced by the same service company.

The Contractor shall before procurement of the measurement system present the type and manufacturer for the Employer's approval.

5.2 Continuous Emission Monitoring System (CEMS)

The Contract Object shall include a complete continuous emission monitoring system (CEMS).

The Contractor shall also provide a CEMS shelter consisting of a weatherproof, environmentally controlled (HVAC) walk-in enclosure to house the flue gas monitors and associated electronics. The shelter shall be completely pre-wired, tubed and self-contained. The enclosure shall be complete with pull terminating field cables and umbilicals for connecting or disconnecting the enclosures. The base floor of the CEMS shelter shall be a minimum of 15 cm above surrounding floor or grade.

The CEMS sampling station shall be located downstream the ID-fan / reheater as last FGT component upstream the stack. To ensure correct measurements, the duct between the ID-fan and the CEMS sampling station shall be in section of the duct with at least 5 hydraulic diameters of straight duct upstream, with two hydraulic diameters downstream the sampling plane, and with at least 5 hydraulic diameters from the top of a stack.

As a minimum, the following parameters shall be monitored and the data shall be shown at the sampling / measurement station as well as continuously be transmitted to the CMS:

- atmospheric pressure (kPa)
- flue gas flow (m^3/s and Nm^3/h)
- flue gas temperature (°C)
- flue gas pressure (kPa)
- H_2O content (% vol.)
- O_2 content (% vol.), wet or dry
- CO_2 content (% vol.), wet or dry
- Dust content (mg/m^3 or mg/Nm^3)
- HCl content (mg/m^3 or mg/Nm^3)
- HF content (mg/m^3 or mg/Nm^3)
- SO_2 content (mg/m^3 or mg/Nm^3)
- NO_X (or NO + NO_2) content, expressed as NO_2 (mg/m^3 or mg/Nm^3)
- NH_3 content (mg/m^3 or mg/Nm^3)
- TOC content (mg/m^3 or mg/Nm^3)
- CO content (mg/m^3 or mg/Nm^3)
- N_2O content (mg/m^3 or mg/Nm^3)
- Hg (mg/m^3 or mg/Nm^3)

The Continuous Emission Monitoring Systems (CEMS) shall be provided with a complete automated system for the Line (line K1) ensuring the suitably calibrated and programmed unit is available at all times.

Employer’s existing CEMS, as described in Appendix E9 Specifications for Employer's existing CEMS, shall be extended with CEMS for the new Line. The concept for the new CEMS shall be identical with the existing CEMS. This include hardware and software concept, calculations, corrections and report generation needed for observance of emission limits according to the integrated permit etc. and stored of all data.

All data from CEMS shall online be transferred to the CMS and be stored in the CMS system. This also included all calculation, correction, alarms, etc.

Regarding selection of monitoring equipment, the following is of importance to the Employer:

- the availability of a service organisation
- minimisation of resources needed for service and maintenance, including that the system is self-calibrating
- high accuracy and low detection limits
- high availability

Calibration gases and all necessary consumables shall be included in the Contract Object and paid by the Contractor until Preliminary Take Over.

The CEMS shall be established according to the provisions and requirements of the Directive 2010/75/EU of the European Parliament and the Council of 24th November 2010 on Industrial

Emissions (Integrated Pollution Prevention and Control), the related BAT reference documents (BREF), EN 14181, EN 14956 and EN 13284 on Stationary source emissions and EN 15267.

The Contract Object include the completion of various quality assurance tasks at installation, including QAL 1 documentation of equipment, QAL 2 test and the reference measurements needed for this test, and all necessary instructions, installations and software for conducting the regular quality assurance tasks, QAL 3 test etc. Execution of QAL 3 shall be included and automated to the extent technically possible.

The calibration parameters of the QAL2 test(s) shall be stored along with the measurement results, so that full traceability is obtained for any re-calculated value.

In addition, sampling ports for manual testing and spare connections shall be installed, meaning that a certain number of spare nozzles/flanges shall be included in the clean gas measuring duct section which might be advisable for 3rd party and calibration measurements as well as for setting additional instruments.

The location and equipment of the monitoring station shall be reviewed with Employer.

Adequate space and clearance shall be arranged around any sampling stations/platforms to allow for the easy insertion and withdrawal of sampling probes and handling associated equipment.

All inlets and outlets shall be galvanic separated. For control and troubleshooting purposes both direct and calculated measuring values (adjusted to normal conditions, 11% O_2, dry flue gas) shall be transferred to the CMS including intermediate values.

In the CMS system, the continuous and historic data from the monitoring station shall be available as actual readings as well as in standard units after corrections for e.g. temperature, pressure, moisture, oxygen and calibration curve (resulting in for instance mg/Nm^3 dry flue gas at 11 % O_2).

5.3 Data acquisition system

The system shall be able to work out environmental reports with averaged data and comparisons with the limits of the integrated permit. The report structure shall comply with the standards, local legislation and the requirements of the integrated permit and of the Authorities. The daily report shall be presented automatically.

Provisions shall be made to connect external signal logging equipment to collect the raw instrument signals and other signals. The intention is to ensure data logging options for use by measurement institute and others. Any such signals shall be galvanic separated at 4-20 mA.

6. DUCTS AND STACK

6.1 Ducts

Flue gas ducts shall be designed with due consideration to the composition, velocity and maximum temperature of the flue gas. Moreover, it shall be ensured that no deposits of fly ash, accumulation of liquid or the like can adversely affect the operation of the Line.

The arrangement of duct bends and other installations shall be optimised in such a way that the pressure loss over the Line is minimised.

Ducts for flue gas shall be constructed by steel plates or, where the conditions so require, by glass fibre reinforced plastic material or acid proof stainless steel. The ducts shall be insulated as described in Appendix A14.4 *Insulation and Cladding for Process*, unless other requirements apply for the particular duct.

Where condensate could occur drains shall direct condensate to the scrubber liquid storage tank.

Corrosion in by-pass ducts and in other ducts during operation and standstill of the Line shall be prevented by appropriate measures. All welds in ductwork that is in contact with the flue gas shall be welded in the inside.

All dampers shall be delivered with pneumatic drives and for the shut-off dampers in the flue gas system where complete tightness is required, special dampers with double sealing and warm shut-off air supply shall be applied. Easy access to all dampers for inspection and maintenance shall be possible.

All necessary expansion joints shall be included. Expansion joints shall be completely tight and of a robust construction, unaffected by vibrations, and they shall be covered on the inside and outside of the ducts so that dust is not collected in the joint.

External and internal braces and stiffeners shall be designed for the largest positive or negative pressure which might occur in the ducts and consideration shall be given to abnormal operating situations such as erroneous closing or the repair and shut-off dampers or the like.

It shall be possible to clean all ducts and they shall be provided with drains to a sump.

The Contractor shall ensure that the flue gas temperature when leaving the stack is well above the dew point in all operating situations within the capacity diagram and taking all relevant ambient temperature conditions within the design limits into account. Consequently, the flue gas duct from Lineto the stack shall be insulated for the purpose of limiting heat loss, if such insulation is required to maintain the flue gas temperature well above the dew point.

6.2 Stack

The existing stack shall be utilized for the Line.

The Contractor shall deliver a new flue gas pipe inside the existing stack, including related equipment such as flanges, fixtures, drains, internal access, electrical, insulation and droplet separator.

The flue shall extend above the shell to the same height as the existing flues from Existing facility.

The pipe material shall be chosen under consideration that continuous operation shall be possible with any flue gas composition arriving from the flue gas treatment system.

The Contractor shall ensure that the flue gas temperature when leaving the stack is well above the dew point in all operating situations within the capacity diagram and taking all relevant ambient temperature conditions within the design limits into account. Consequently, the flue shall be insulated for the purpose of limiting heat loss, if such insulation is required to maintain the flue gas temperature well above the dew point.

As a supplementary safeguard against droplet fallout from the emitted gas a droplet eliminator shall be installed in the top of the stack pipe.

Condensate/water shall be drained from the bottom and directed to a suitable drain tank of 1 m^3 net volume to be installed in the existing stack basis. From this drain tank the liquid shall be transferred to the existing IBA wastewater pit.

A manhole with tightly bolted seals shall be installed on the base of the flue gas pipe for maintenance and inspection access.

The maximum permissible Sound Power Level (LWA) of the stack is defined in Appendix 14.3 *Acoustic Noise and Vibrations*.

Connection to the existing earthing system is to be included.

7. SILOS, TANKS AND STORAGE FOR CONSUMABLES AND PRODUCTS

All tanks, silos and other storage systems included in the Line shall, unless otherwise stated, be placed within the building enclosure. Required capacities of tanks and silos are described in Appendix A13 *Process and Design Data*.

Tanks and containers for chemicals shall be placed in separate chemical room(s) with independent room ventilation and shall have safe and easy access from the outside for filing of tanks and/or exchange of containers.

For limits of supply reference is made to Appendix A18 *Limits of Supply* and consumables are specified in Appendix E3 *Specifications for Employers consumables*.

7.1 General requirements for silos, other storage systems and tanks

7.1.1 MEASUREMENTS

Silos / storage systems shall be equipped with weighing cells.

Tanks shall be equipped with suitable mass determining measurements, e.g. level plus calibrated level-capacity-curve corrected mass calculation.

The weight of the silo / storage system content or tank content shall be measured with 2% accuracy or better.

Consumptions shall be measured continuously with an accuracy of 1% on 12-hourly basis, or better, based on silo or tank content.

In the case of several, significant consumers, measurement shall be established for each.

7.1.2 FILLING AND VENTS

Silos for powder products shall have a small bag filter on top of silo. The safety valve and the bag filter shall be vented over the roof. The vents shall be arranged and equipped with sampling ports so that dust concentration measurement can be made by spot sampling.

The Tenderer shall state how a damaged bag is detected.

Filling arrangements are included for all consumables used in the Contract Object.

For safety reasons the filling pipe for powder products shall be equipped with pneumatic pinch valve operating on the ΔP over the silo (dust filter) and the level in the silo. Before the pinch valve is activated an alarm (light or horn) shall warn the lorry operator.

7.2 Storage System for Fresh Adsorbent (Activated Carbon)

7.2.1 GENERAL

All equipment for activated carbon shall be classified according to ATEX and all necessary protective initiatives shall be taken.

7.2.2 EXISTING STORAGE SYSTEM FOR FRESH ADSORBENT (ACTIVATED CARBON)

The Employer has an existing storage system for activated carbon, i.e. big bag system. The capacity is estimated to be sufficient for use for Line in addition to the Existing facility.

Consequently, the fresh adsorbent used for the Line shall be activated carbon from the existing storage system.

The Contract Object shall include all necessary Contract Object for connection to the existing storage system including but not limited to establishment of necessary connection flanges at the existing storage system, all necessary distribution, dosing equipment (piping, valves etc.), preparation devices and piping.

7.2.3 NEW BIG-BAG SYSTEM FOR FRESH ADSORBENT (ACTIVATED CARBON) – OPTION 3

A big-bag system for activated carbon shall be offered as an option. Refer to option 3 described in Appendix A21 *Options*. In case Option 3 is chosen by the Employer, the existing storage for activated carbon shall not be connected to and used for the Line .

Exchange of bags shall be easy and seamless without any interruption of the dosing in operation. Equipment for lifting of bags from the ground into the storage position shall be motorized.

The outlet arrangement to the downstream dosing system shall be guided through the hopper. If necessary, a vibration system shall be installed. For insulation against the downstream system a shut of valve shall be included. Emptying to the dosing station shall be continuous, smooth and controlled in a way that excessive flooding of the downstream dosing system is prevented.

The content of the big-bag during dosing of the material shall be monitored continuously, locally and remote, e.g. by weighing cells, electromagnetic waves or other measurements.

It shall be prevented that dust escapes into the surroundings.

Local controls shall be included to allow the operator to monitor the filling degree and exchange bags.

7.3 Silo for Fresh Absorbent (Lime)

It is anticipated that the fresh absorbent is hydrated lime ($Ca(OH)_2$) or quick lime (CaO).

7.3.1 EXISTING SILO FOR FRESH ABSORBENT (QUICK LIME)

The Employer has an existing storage silo for quick lime. The capacity is estimated to be sufficient for use for Line K1 in addition to the Existing facility.

In case the Contractor chose to use quick lime (CaO) as absorbent the Contract Object shall include all necessary Contract Object for connection to the existing silo including but not limited to establishment of necessary connection flanges at the existing storage silos, all necessary distribution, dosing equipment (piping, valves etc.), preparation devices and piping.

7.3.2 NEW SILO FOR FRESH ABSORBENT (HYDRATED LIME)

In case the Contractor does not chose to use quick lime (CaO) as absorbent, a complete absorbent silo including the necessary auxiliary and control equipment shall be included in the Scope of Contract Object and fulfil the stated requirements.

- The silo will be filled in lots corresponding to one full load of a lorry and it shall be possible for a large lorry to access the loading station easily. A local control panel for start and stop of loading shall be included. The control panel, functioning and the display of the local control panel shall in overall be similar to other control panels in the Complete plant. The local control panel shall be accepted by the Employer.

- The silo shall be equipped with a bridge breaking system like vibrators on the cone and a hammering system on the shell side.

- The silo shall be equipped with 'slide gate'. Stair access to the bin vent filter, fill pipes and hatchways at the top shall be included.

7.3.3 NEW SILO FOR FRESH ABSORBENT (QUICK LIME) – OPTION 4

A new storage silo for quick lime (CaO) shall be offered as an option. Refer to Option 4 described in Appendix A21 *Options*. In case Option 4 is chosen by the Employer, quick lime (CaO) shall be used as absorbent and the existing storage for quick lime (CaO) shall not be connected to and used for the Line.
The silo system shall receive and contain the reagent.

The silo shall be equipped with bridge breaking equipment. A system shall prevent accidental outlet, for instance by free flowing.

The option includes lime slaking systems. Quick lime shall be hydrated by dedicated process equipment.

If necessary, the system shall include an intermediate storage silo to be equipped with equipment to supply all consumers of the FGT unit.

7.4 Silo for Residual Products

The Employer has two existing storage silos for end product. The capacity is estimated to be sufficient for use for the new Line in addition to the Existing facility.

The Contract Object shall include establishment of all necessary Contract Object for transport from the FGT system and connection to the existing silos, including but not limited to establishment of necessary connection flanges at the existing storage silos, all necessary distribution, dosing equipment (piping, valves etc.) and piping, for storage of the total amount of boiler ash and flue gas residue from the Line.

It shall be possible to transfer an end product stream to any of the two existing silos.