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FUNCTIONAL DESCRIPTION

Description :	**CTP VOXcube 3-075**
Client	**JOHN ZINK**
End User	**HES HARTEL**
Location :	**Rotterdam, TheNetherlands**
Project Nr. :	**18-00540**
Customer Ref. :	**MVCP00112**

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VOXcube 3-075

Version: 1/2019
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[redacted] HES NL

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Contents

1 USER INSTRUCTIONS

This functional description provides important information on your VOXcube 3-075 and has to be used as documentation for all works on the system. Please consider the process flow diagram as the basis of the CTP manual. You can find it in your CTP system documentation, chapter "3. flow sheets".

The functional description is part of the CTP system. A complete set must be kept in the direct proximity of the system, in a weather-protected place, where it is available for the personnel at any time.

The company management of the customer are required to ensure that all personnel working with the system have read and understood this functional description before starting any work. Strict compliance with all specified safety notes and instructions is a basic requirement for safety at work.

Moreover, the accident prevention guidelines and general safety regulations applicable at the place of use of the CTP system must also be complied with.

Illustrations in this manual are intended to facilitate basic understanding and may differ from the actual design of the system.

Please find the specification and all other technical data concerning your VOXcube 3-075 in the appendix of the specification manual and in the CTP system documentation.

1.1 The structure of the CTP system documentation

This functional description is part of your CTP system documentation, which contains detailed information about the
VOXcube 3-075:

- user manuals
- CTP training material
- flow sheets
- layout drawings
- installation plans
- technical specifications
- supplier literature for built-in components
- spare part lists
- protocols and certificates
- parameter lists
- alarm list

The CTP manuals itself consists of the following parts:

- functional description
- operator manual
- maintenance manual

1.2 The CTP manual parts

Functional description

This part of the manual has been written for all persons, who will be in contact with the CTP system – operators, users, maintenance personnel, for example – as well as those, who are just interested in the way the system works.

Here you will find information on liability, warranty, staff qualification and basic info's on safety devices and equipment. There is a detailed description of the VOXcube 3-0785, its components and functions as well as the different operation modes and the processes behind them. In the appendix you will find your specific system data and process values.

Operation manual

This part of the manual is intended for all persons, who will operate the VOXcube 3-075.

Here you will find a detailed description of the system controls. The various operating and setting elements of your specific system controls will be explained with the help of numerous screenshots and tables.

Maintenance manual

This part of the manual has been written for all persons, who carry out mechanical and electrical maintenance works at the VOXcube 3-075.

Here you will find all safety information regarding maintenance and repair works in and at the system. You learn how to enter the system safely, how to inspect it etc. There is an inspection and maintenance plan, a lubrication plan as well as a step by step guide for various regular and specific maintenance works. You also learn about possible faults and troubleshooting, what to do if repair works are necessary and how to handle spare parts, closing down, dismantling and disposal.

1.3 Liability

This functional description has been produced under due consideration of valid standards and regulations, the present status of technology and our years of knowledge and experience.

Before working with the VOXcube 3-075, the company management of the customer is required to ensure that all persons involved have read and understood the relevant chapters of this description.

Damages to the CTP air pollution control system

CTP cannot be held liable for damages to the CTP system resulting from:

- nonobservance of the CTP manuals
- inappropriate or improper use or operation of the CTP system
- a way of operation not according to CTP specifications (e.g. a raw gas composition with a negative effect on the system operation or life)
- the employment of untrained operation and maintenance personnel
- faulty or negligent maintenance
- the use of spare parts, which have not been delivered by CTP, the use of spare parts, which are not mentioned in the CTP spare part list
- inappropriate or incorrectly installed spare parts
- unauthorized repair and maintenance work or technical changes to the CTP system

Damages to the customer's system

CTP is not responsible for damages to the customer's system, which has been caused by a standstill or failure of the CTP system, as well as therefrom arising costs.

Apart from this, the contractual obligations agreed upon by CTP and the customer, the agreed general terms and conditions, and the legal regulations valid at the time of contract do apply.

As soon as the start-up protocol is signed or at any contractually specified earlier date, the responsibility for the system operation and insurance passes on to the customer (see "Customer's responsibilities" on page 4).

1.4 Warranty terms

The warranty terms are provided in your CTP order confirmation as well as in the underlying contract.

To keep your claims, you need to document continuously during the whole warranty period that the system is operated according to the instructions in the CTP manuals.

Refer to the operation manual for information about the data backup.

2 RESPONSIBILITIES AND QUALIFICATION

2.1 Customer's responsibilities

Definition "customer"

The customer is defined as the legal person, who operates or controls the CTP system, or who delegates the system operation to a third party. Regardless whether the customer himself operates the system in person; it is the customer who, in obligation to CTP, has the legal responsibility for the protection of the users, the personnel and third parties.

As soon as the start-up protocol is signed or at any contractually specified earlier date, the responsibility for the system operation and insurance passes on to the customer (see "Customer's responsibilities" on page 4).

Provision of personnel

The customer must

- provide qualified personnel for the operation and maintenance of the CTP system.
- make sure that all employees, who are concerned with the installation, start-up, operation, maintenance, repair or dismantling of the VOXcube 3-075 have received the CTP manuals and confirm this by signing the respective form (for an example of this form please refer to the appendix).
- clearly specify the responsibilities for operation, fault clearance, maintenance and cleaning.
- be familiar with the industrial safety regulations and must implement them accordingly.
- supply the personnel with the necessary protective equipment.
- make sure that the personnel know what to do in case of an emergency.

Training of personnel

After the CTP system training the customer is responsible for supplying any new employees with the CTP training material.

For the training documents refer to the CTP system documentation of the VOXcube 3-075, chapter "Manuals".
A list of all participants is included in chapter "Protocols and certificates".

Constructive measures

The customer must make sure that

- the operating and maintenance personnel always have safe access to the system and the control panels.
- unauthorized persons or animals have no access to the CTP system.
- there are no changes made to the CTP system without authorization by CTP.
- the system is protected from damages or other negative (external) influences.
- the system lighting is at least up to the local standards and regulations.

- first aid equipment and suitable fire extinguishers are installed according to the local standards and regulations.
- there is free access for emergency vehicles in case of an emergency.

2.2 Personnel requirements

Persons, who are responsible for operating, maintaining, repairing or dismantling the CTP system need to

- be skilled accordingly.
- confirm with their signature that they have received the CTP user manual or at least the parts of it, which are relevant to them.
- confirm that they have been trained on the CTP system by using the CTP training material (see CTP system documentation, chapter "manuals") before they start to work with the system.
- use their personal protection equipment provided by the customer.

WARNING!

Risk of injuries in case of insufficiently qualified personnel!

Improper use can cause considerable personal injury and material damage. Therefore:

➢ Stay away from the plant, if you are not properly qualified.

Operation personnel

The operation personnel must:

- understand the system functions and must be able to operate the system.
- be able to identify system faults and assist CTP in fault clearance as well as in implementing improvements.
- pay attention to alarms and eliminate the causes instantly.

Personnel for mechanical and electrical maintenance

The maintenance personnel must be able to

- carry out maintenance works on their own.
- operate the system on their own for maintenance purposes after a CTP operation training.

We recommend you have CTP maintain your system mechanically and electrically once a year by obtaining a CTP maintenance contract.

3 SAFETY

This chapter informs you about general measures for the safe use of the VOXcube 3-075 and about potential dangers when operating the system.

The safety regulations in this description are to be considered as minimum requirements and must be complied with at any rate.

The system can only operate safely as long as the maintenance requirements are met in accordance with the CTP maintenance manual.

Moreover, the accident prevention guidelines and general safety regulations applicable at the place of use of the CTP system must also be complied with as well as the national health and safety regulations.

3.1 Explanation of safety words

The following safety words are used throughout this functional description to emphasize important and critical safety-related information concerning the VOXcube 3-075:

DANGER!

indicates an imminently hazardous situation, which, if not avoided, will result in death or serious injury.

WARNING!

indicates a potentially hazardous situation, which, if not avoided, will result in death or serious injury.

CAUTION!

indicates a hazardous situation, which, if not avoided, will result in minor or moderate injury.

NOTICE!

indicates a situation, which, if not avoided, will result in property damage.

3.2 Intended use

The CTP air pollution control system has been designed solely for cleaning the flue gas from the customer's process. The raw gas content and concentration needs to be kept within the limits of the contractual specifications.

The CTP system is only operated according to the intended use if all works at the system are carried out in accordance with the CTP manuals and the system is in a good working state.

In case there is a change in the use of the system, a change of the customer's process or a constructional change in the system, actions must be taken to ensure the safe and intended use of the VOXcube 3-075. In any of these cases the customer is advised to contact CTP beforehand.

3.2.1 Foreseeable misuse

Case 1: The contractually specified system limits are not adhered to.

- Do never exceed the system limits.
- In case you would like to increase the performance of the system, contact CTP.

Case 2: The process data changes: There is a change in the content and/or concentration of the customer's raw gas or a change in the system flow.

- Contact CTP as quickly as possible. CTP will analyze the new process data and adjust the system to the new situation if necessary. That way damages and/or the emission of harmful gases can be avoided.

3.3 Safety devices and equipment

3.3.1 Emergency stop buttons

The VOXcube 3-075 is equipped with emergency stop buttons. They are located at the following positions:

- in the container (control cabinet +S60)
- in front of the RTO (valve box)
- spares for customer connections

The emergency stops buttons overrule the system control. If one of the buttons is pressed, the electrical power of all safety relevant system components is switched off. The electrical heater is switched off and all the other equipment are stopped instantly. This process regards the software as well as the hardware.

Emergency stop process

The following processes are executed in case of an emergency stop:

1. The VOXcube 3-075 switches to emergency stop.
2. The supply voltage to all valves is interrupted.
3. The supply voltage to the electrical heater is switched off (“pulse lock” at Thyristor controller).
4. The main blower and preheating blower are switched off (“safe torque off” at VSD).
5. The cooling blower of electrical heater box is switched off.

The following elements remain active/live:

- the control voltage (230/400 V)
- the PLC and HMI - the process values are still displayed
- all cabinet fans
- the electrical sockets
- the lights
- frequency converters (with locked release)
- thyristor controller (with pulse lock)

Please find an overview of the switched off or disconnected devices in the CTP system documentation, chapter "Electrics" > "Loop diagrams".

NOTICE!

Risk of property damage due to misusing the emergency stop!

Whenever an emergency stop is activated, the system is stopped extremely fast, leaving out important processes; damages due to corrosion, overheating as well as odor release could be the result.

- Do never use an emergency stop instead of the regular stop procedure.

Restart after emergency stop

After an emergency stop button has been activated, it must be unlocked to enable a restart.

⚠ WARNING!

Risk to life by uncontrolled restart!

The uncontrolled restart of the air pollution control system may represent severe threat to life.

- Make sure before restarting the system that the cause for the emergency stop has been eliminated.
- Check if all safety devices have been re-installed and are in working condition.
- Do unlock the emergency stop button only if the safe situation is ensured.

Restart procedure

1. Ensure that the dangerous situation is banned.
2. Unlock the emergency stop button by turning the button or by unlocking it with a key (depends on the model).
3. Press the reset button on the control cabinet to reset the emergency stop relay.
4. Reset the frequency converters at the VSD display
5. Reset the thyristor controller
6. Quit all active alarms on the display/user interface.

Now the system is ready for restart.

3.4 Safety tags: pictograms

The following safety tags are mounted on your VOXcube 3-075. The following picture represents an example.

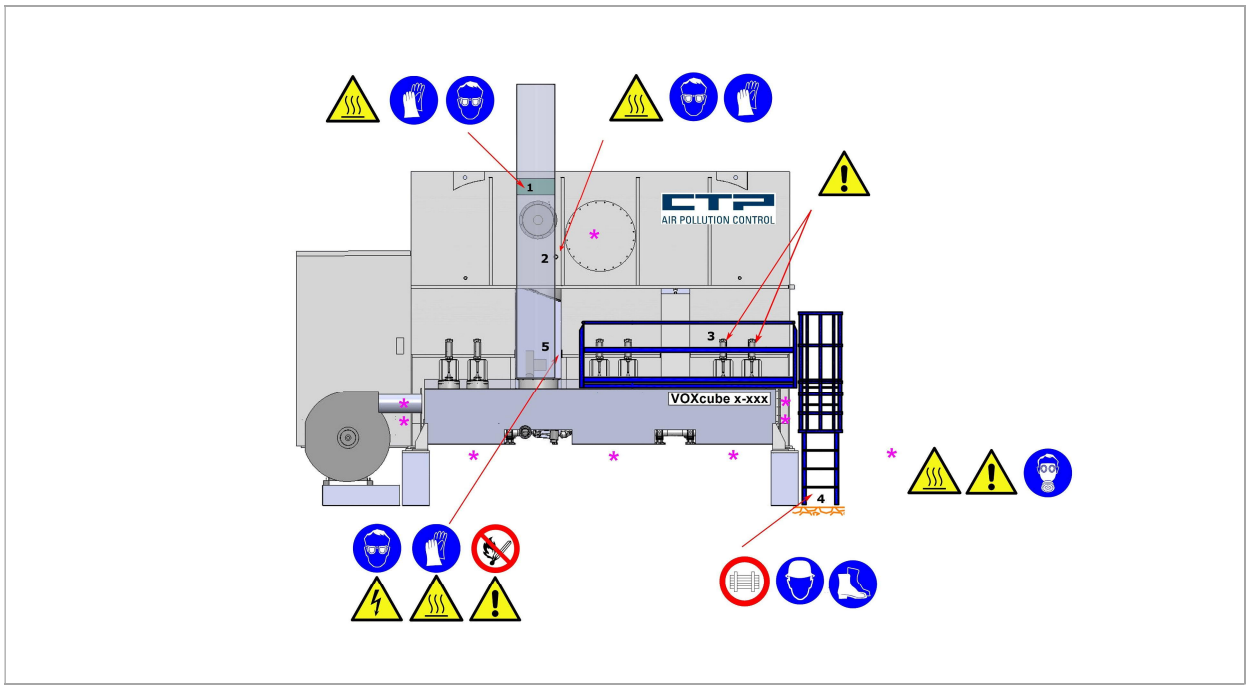

Figure: System pictograms

Please find the explanation of the symbols as well as their positions on the system below.

Symbol	Explanation
 max. 300 kg/m²	Stack or store: max. 300 kg/m²
	No smoking, no fire, no open light.
	Danger - high voltage
	General danger
	Danger - hot surface
	Direction sign for emergency exits
	Emergency exit
	Fire extinguisher (to be installed by the customer)

3.5 Personal Protective Equipment (PPE)

Personal protective equipment (PPE) is clothing, equipment or substances designed to be worn by someone to protect them from risks of injury or illness.

⚠ WARNING!

Danger of injury for not wearing the personal protective equipment (PPE)!

- Make sure that all persons involved with works at the system, observe the regulations and use their PPE.
- Ensure that untrained personnel (external personnel, customers etc.) are always accompanied by an authorized person and wearing the respective PPE when staying near the air pollution control system.

4 SYSTEM DESCRIPTION

The system contains the following sub-systems:

- RTO system (VOX 3-175) with the following components:
- Main blower
- LEL protection system with retention tank
- LEL and O2 dilution
- Raw gas preheating system
- Reactor
- Three bed system
- Valve box
- Hot bypass
- Bake out and purge system
- Electrical heater
- Pressurized air system
- Electrics

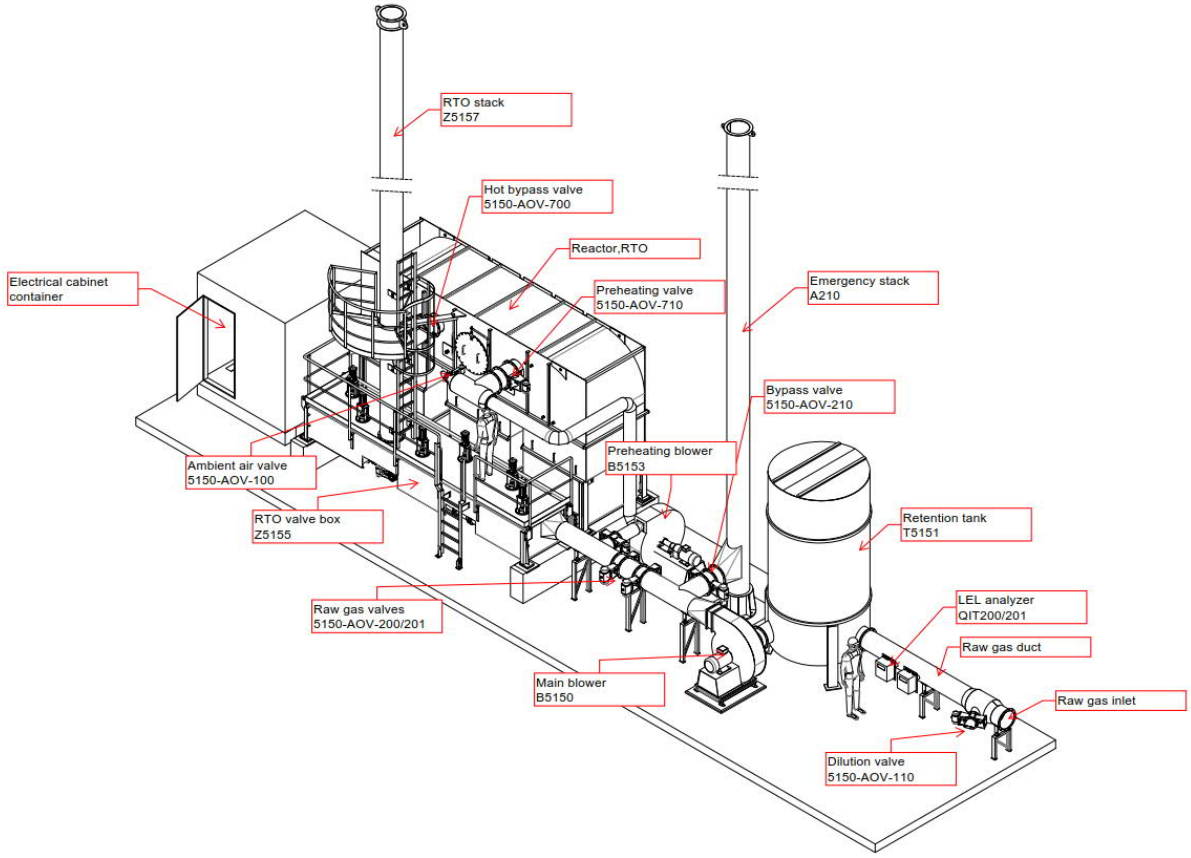

Figure: System overview

4.1 RTO unit

4.1.1 Process description

The process raw gas is pressure fed into the RTO system. Immediately after the reception of the raw gas, there are two LEL sensors installed followed by a retention ductwork. This combination provides sufficient time for the bypass valves to open and raw gas inlet valves to close; that is to divert the raw gas with too high LEL concentration from the RTO to the bypass.

Before the raw gas entering the RTO, the raw gas is pre-heated by using hot air sucking from the combustion chamber to avoid condensation. After this the raw gas is hot enough to be fed into the 3-bed RTO without the risk of condensation in the system.

The electrical heater provides the required energy for heating up during start up and in times when not enough organics are present in the waste as to create enough heat in the system.

The system also includes a hot bypass which feeds hot gas from the combustion chamber directly to the clean gas. By doing this, overheating of the RTO due to the high organic mass flow is prevented.

4.1.2 Components

4.1.2.1 Main blower

The raw gas is fed through the system by a blower. As the system is a pressure-side system, the blower is placed upstream the plant.

The blower is equipped with a pressure controlling system to ensure a constant admission pressure and a regulated flow.

Whenever the system is in start-up, standby, or cool down mode, the raw gas must be led via a customer production bypass directly into the atmosphere, else the customer process must be stopped.

4.1.2.2 LEL protection system with retention tank

Because of an internal ignition source and high temperature in the RTO-system, raw gas streams entering the RTO should always have a concentration of organic components below 20% LEL

The system is equipped with a LEL (Lower Explosive Limit) detection and control system as well as a retention tank for the raw gas. The LEL sensors are from FID types (Flame Ionization Detector) which are measuring the raw gas concentration. Via the dilution air valve this LEL limit can be controlled by adding ambient air to the waste gas.

In case the LEL level exceeds the high high limit, the raw gas valves are closed immediately, and the RTO goes to mode STANDBY. The emergency stack in the raw gas duct opens accordingly. The retention tank is designed to delay the raw gas, to ensure that during the measurement and evaluation of the LEL concentration and the closing of the raw gas valves, no high concentrated raw gas can enter the RTO.

After a trip due to high LEL limit the retention tank needs to be purged to remove all high concentrated raw gas before a restart is allowed. After the alarm has been acknowledged in the PLC system, the purge sequence will start. Ambient air is sucked via the dilution air valve to the emergency stack by the main blower. The required flow rate is monitored by a sensor. The purge time is also monitored and is only running if the flow is above the minimum limit and the LEL level is below high limit.

After this purge time is elapsed, the raw gas condition is reset, and the RTO can be switched to operation mode again.

All required conditions for this pure sequence will be realized in the failsafe part of the PLC.

4.1.2.3 LEL dilution

The raw gas dilution is used to dilute the raw gas in case of excessively high concentration. Ambient air is added via the dilution air valve to the raw gas line.

This dilution is also used to dilute the raw gas in case of less oxygen is measured in the stack.

The flow through the dilution air valve depends on the concentration of contaminants in the raw gas or oxygen in the stack.

This dilution air valve is also used for the purge sequence of the retention tank and pipe in case of a LEL high level alarm trip.

4.1.2.4 Raw gas preheating system

The preheating system is used for preheating the raw gas. The valve box and the cone area must be preheated before the raw gas is fed into the plant. This is necessary to avoid condensation by keeping the raw gas temperature above the dew point.

The hot air from the combustion chamber is sucked via the preheating valve and preheating blower to the raw gas line. The ambient air valve is also used to cool the preheating system in case of too high temperature.

The preheating blower is also used for the necessary ambient air flow through the RTO during heat-up and mode STANDBY. During start-up the ambient air valve is used, so no raw gas enters the system at that stage. The air volume required during start-up corresponds to about 20-30 % of the maximum operation flow.

The ambient air valve is used also when the system is in standby mode, or in cool down mode.

4.1.2.5 Reactor

The reactor consists of 3 heat exchanger towers, which are connected with each other via a shared combustion chamber. Ceramic honeycombs are used as heat exchanger elements. The reactor is equipped with a special type of inner and outside insulation, which minimizes the energy loss.

4.1.2.6 Three bed system

During operation, the raw gas is fed through the regenerative heat exchanger tower A and is preheated to near combustion temperature. In the combustion chamber, the contaminants are oxidized. The resulting combustion heat reduces the necessary electrical heater power in relation to the level of contaminants. For concentrations near auto thermal level the electrical heater will be switched off.

For the specification of the VOXcube 3-075 please refer to the appendix.

The hot purified gas, which comes from the combustion chamber, streams through the regenerative heat exchanger tower B and transfers its heat into the storage mass of the ceramic honeycomb blocks. In the meantime, the heat exchanger C is purged.

After about two minutes the raw gas is transferred to heat exchanger B automatically. The clean gas leaves the combustion chamber through bed C. Meanwhile bed A is purged in order to remove any remaining waste gas. The purge air is disposed of through the combustion chamber and heat exchanger C. The raw gas now enters at bed C and leaves the combustion chamber at bed A, while bed B is purged.

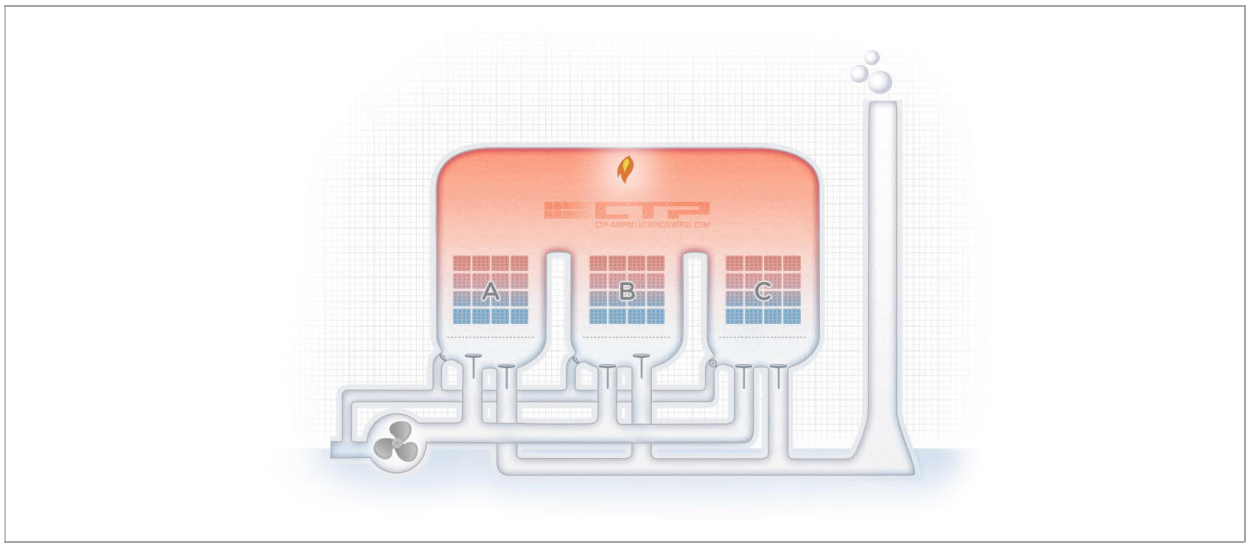

Figure: Switching cycle 1 - pressure side system

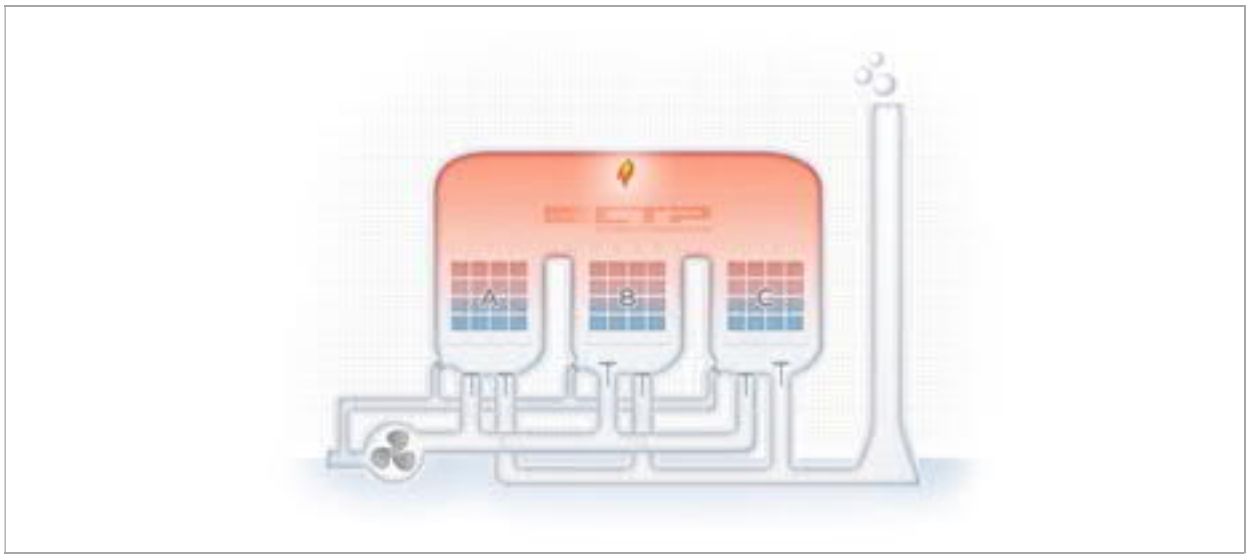

Figure: Switching cycle 2 - pressure side system

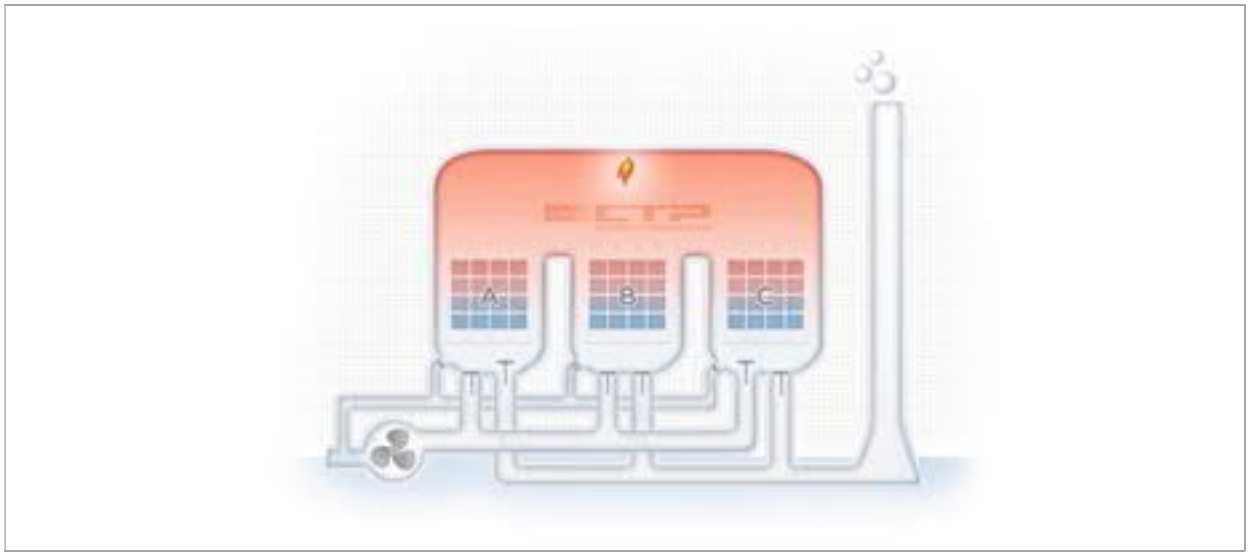

Figure: Switching cycle 3 - pressure side system

4.1.2.7 Valve box

The valve box consists of a raw gas channel, a clean gas channel, the poppet valves and the cones. The raw gas duct is located on the side facing the VOXcube 3-075 while the clean gas duct is located on the plant averted side. At the outer sides of the two channels, there are the valve box cones, which connect the raw/clean gas channel with the heat exchangers. The poppet valves, which are installed in the base plates of the channels, switch the direction of the raw gas flow through the heat exchangers.

For the standard configuration of the VOXcube 3-075 please refer to the instrumentation layout, which is included in your CTP system documentation.

4.1.2.8 Hot bypass

The VOXcube 3-075 is equipped with a hot bypass, which forms a direct connection between the combustion chamber and the clean gas duct/stack (after the valve box). In case of high concentrations - above auto thermal concentration - a partial flow of hot clean gas is extracted from the combustion chamber via the hot bypass valve in the stack. The flow through the hot bypass depends on the concentration of contaminants

In cooldown mode, the hot bypass can also be used for cooling the combustion chamber in addition to the ambient air valve.

4.1.2.9 Bake out and purge system

To remove volatile organics in the third tower after switching main valves, a purge step is included in the sequence. The preheating blower is also used to provide the required purge air flow of ~10% of the nominal flow (for detailed description of the tower purging, see chapter RTO main valve cycle).

In bake out mode, the preheating blower sucks the hot air from the combustion chamber through the ceramic blocks back to the raw gas to heat up the grid of the tower up to 400°C. In this mode a required air flow of ~30% of the nominal flow is used (for detailed description of the bake out mode, see chapter Modes of the plant)

This blower is controlled by a under pressure.

4.1.2.10 Electrical heater

The heater is built with horizontally arranged heating elements in a rectangular housing. It is gas tight with a sealing at the flange.

The connection boxes of the electric heating are protected against over-temperature by two temperature sensors.

The electrical heater is required for the startup of the RTO system. It is also used for keeping the system on temperature in the different operation modes.

The power to the RTO main heating, hence the average temperature of the combustion chamber is controlled by a thyristor controller. The communication takes place via Profinet interface between PLC and thyristor.

When the combustion chamber control is activated, the electrical heater starts and heat the combustion chamber up by using an adjustable ramp.

The ramp starts from the actual combustion chamber temperature.

To extend the heating rods´ lifetime, heating power per element is limited to 10kW during startup (TICA300 < 600°C)

As soon as the combustion chamber has reached the adjustable combustion chamber limit 1, the RTO standby mode is activated.

In standby and operation mode, the controller of the electrical heater keeps the combustion chamber temperature stable.

4.1.2.11 Pressurized air

The conditioned pressurized air (oil-free and dry) is provided by the customer.

The VOXcube 3-075 is supplied through an extra maintenance unit, which is equipped with a minimum pressure switch. If the system pressure is lower than the minimum value, which is set to 4 bar, the system is switched to quick stop.

A pressure buffer always needs to be available on site to ensure that the valves can be closed in case of a power failure.

4.2 Electrics

4.2.1 Electric power supply, UPS supply

To be defined

4.2.2 Control cabinet

Load cabinet

- All required power supplies from customer are connected to the load cabinet.
- The load cabinet includes all load supplies for blowers, electrical heater and the common supplies and functions like cabinet lights, cabinet fans a.s.o.

Control cabinet

- The control cabinet includes the complete control system of the RTO unit and the emergency stop system.

Control voltage

- 230VAC, produced in the load cabinet.
- 24VDC, produced in the control cabinet.
-

For the according wiring diagram, please refer to the CTP system documentation of the VOXcube 3-075, chapter "Electrics" as well as to the wiring diagram bags, which are placed in the control cabinets.

4.2.3 Control system

The PLC works with non- fail-safe as well as with fail-safe input and output cards. All safety relevant components are read and controlled via fail-safe cards.

There is an Ethernet interface between the PLC and HMI system.

For a control system overview, please refer to the CTP system documentation of the VOXcube 3-075, chapter "Electrics" > "Input-output list".

4.2.4 Instrumentation

For details on the instrumentation please refer to the CTP system documentation of the VOXcube 3-075, chapter "Instrumentation".

4.3 Control circuits

4.3.1 Controllers in general

Every controller is locked by an interlock, which only releases the controller for operation, if its release conditions are met. That way, the safe operation of the controllers is guaranteed.

Controllers can be operated in two ways, automatically or manually.

Manual mode

In the manual mode a fixed value is written directly to the output (e.g. control valve). Manual values are entered in percent and are adjustable from 0 to 100%. Three different manual values can be used:

- Manual value 1 (MV 1)
- Manual value 2 (MV 2)
- Manual value 3 (MV 3)

Automatic mode

In the automatic mode the controllers try to control a process value. The following parameters influence this process:

- Proportional value (gain)
- Integration time (Ti)
- Derivative action time (Td)

Three different set values can be used:

- Nominal value 1 (SP 1)
- Nominal value 2 (SP 2)
- Nominal value 3 (SP 3)

During normal operation the plant can switch between different set points or even from automatic to manual mode and vice versa.

4.3.2 Pressure control circuit for raw gas flow

- *Setpoint:* Negative pressure value in mbar, set at HMI
- *Process value:* Raw gas pressure 5150-PIT-200
- *Controller output:* Speed control of main blower B-5152 via frequency converter
- Controller type: PID controller

Description:

The pressure in the raw gas duct at the customer interface is monitored by the pressure transmitter 5150-PIT-200.

To take over the raw gas from the customer process, it is necessary to maintain a negative pressure in the raw gas duct and this is ensured by controlling the main blower B-5152.

The setpoint for this control loop is a negative pressure value, set at the controller pop-up at the HMI. The controller sends his control value to a frequency converter which changes the blower speed to reach the given setpoint value.

If limit values are exceeded, alarms and corresponding actions will be activated.

The main blower B-5152 and its control function can be started and stopped by the operator at the HMI screen, if the RTO is not in mode OPERATION or BAKEOUT OPERATION.

For RTO mode OPERATION and BAKEOUT OPERATION the main blower B-5152 must be active and in pressure control mode.

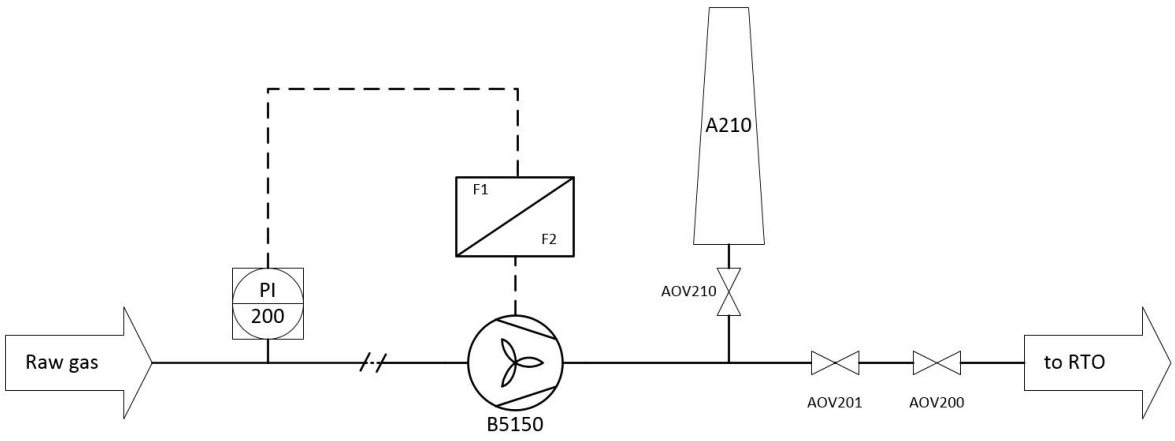

Figure: Pressure control circuit for raw gas flow

4.3.3 Dilution air control circuits

4.3.3.1 Dilution air control circuit for raw gas concentration

- *Setpoint:* VOC concentration value in *%* LEL at RTO inlet, set at HMI
- Process variable: LEL concentration in raw gas 5150-QIT-200 or 5150-QIT-201
- Controller output: Position of dilution air valve – 5150-AOV-110
- Controller type: PID controller

Description:

The VOC concentration of the raw gas is monitored by two independent LEL sensors 5150-QIT-200 and 5150-QIT-201.

The VOC load of the raw gas changes, depending on the current customer process. To ensure an RTO operation, also with a very high VOC concentration in the customer raw gas, it is necessary to dilute the raw gas stream with ambient air to keep the LEL concentration below the maximum allowed LEL level at the RTO inlet.

For the dilution, an ambient air inlet in the raw gas duct, with the dilution control valve AOV 110, is foreseen. With opening the dilution valve 5150-AOV-110, ambient air gets sucked into the raw gas duct due to the negative pressure inside the duct.

The setpoint of this control loop is a %LEL value, set at the controller pop-up at the HMI.

The controller sends his control value to the dilution air valve 5150-AOV-110 which changes the ambient air flow to reach the given setpoint value.

If limit values are exceeded, alarms and corresponding actions will be activated.

The dilution air control circuit for raw gas concentration is released and active in RTO mode OPERATION and BAKEOUT OPERATION.

4.3.3.2 Dilution air control circuit for oxygen content

- *Setpoint:* Oxygen content value in Vol%O2 in the RTO stack, set at HMI
- Process variable: Oxygen concentration in clean gas QIT-502
- Controller output: Position of dilution air valve 5150-AOV-110
- Controller type: PID controller

The oxygen content in the clean gas is monitored by an oxygen sensor QIT-502.

For a complete combustion of the VOCs in the RTO, a minimum oxygen content in the combustion chamber is required. The oxygen content of the raw gas, and therefore in the combustion chamber, can be raised by adding ambient air to the raw gas stream.

An ambient air inlet in the raw gas duct, with the dilution control valve AOV 110, is foreseen. With opening the dilution valve 5150-AOV-110, ambient air gets sucked into the raw gas duct due to the negative pressure inside the duct.

The setpoint of this control loop is a %VolO2 value, set at the controller pop-up at the HMI.

The controller sends his control value to the dilution air valve 5150-AOV-110 which changes the ambient air flow to reach the given setpoint value.

If limit values are exceeded, alarms and corresponding actions will be activated.

The dilution air control circuit for oxygen content is released and active in RTO mode OPERATION and BAKEOUT OPERATION.

4.3.3.3 Dilution air control valve 5150-AOV-110

There are two control loops which sends his control signal to the control valve 5150-AOV-110:

- Dilution air control circuit for raw gas concentration
- Dilution air control circuit for oxygen content

The two control loops are always active at the same time and the control signal with the higher value is leading and controlling the control valve.

In case, the negative pressure in the raw gas duct, measured by the pressure sensor 5150-PIT-200, is going towards zero and exceeds the alarm limit, the valve 5150-AOV-110 closes immediately to prevent an emerge of raw gas to ambient.

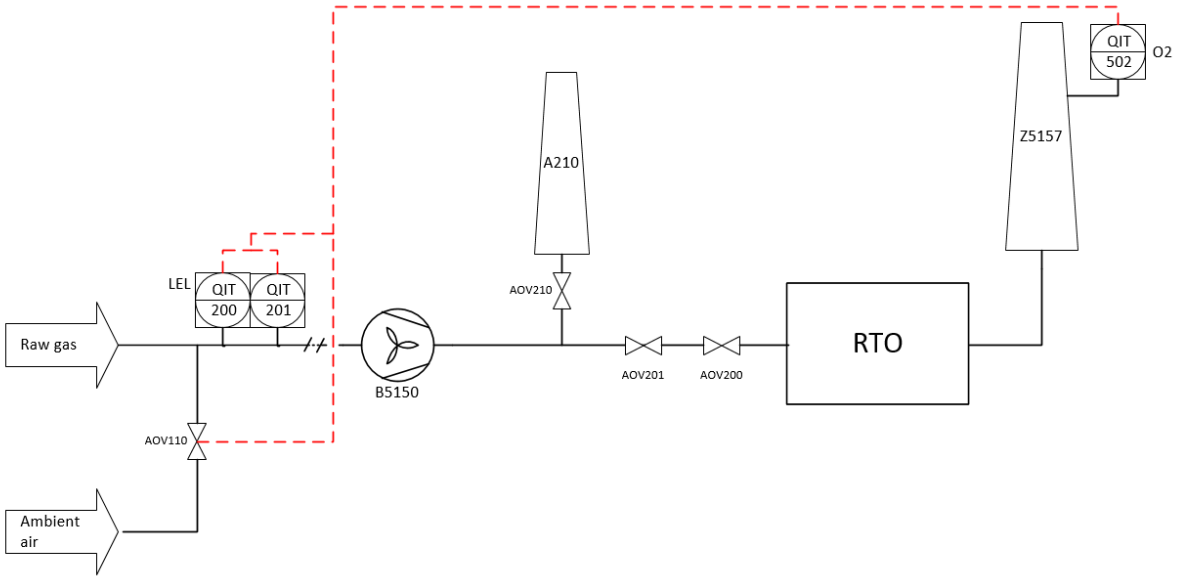

Figure: Dilution air control circuit for raw gas flow and O2 content

4.3.4 Temperature control circuit for raw gas preheating

- *Setpoint:* Temperature value in °C of raw gas stream at RTO inlet, set at HMI
- Process variable: Raw gas temperature 5155-TT-201
- Controller output: Preheating control valve AOV-710
- *Controller type:* PID controller with ramp function

Description:

The raw gas temperature at the RTO inlet is monitored by a temperature sensor TT-201.

The customer raw gas stream possibly contains Sulphur, which can cause a damage in the RTO system, especial in the valve box. In case the surface temperature of the ducts and the valve box is below the dew point of Sulphur, the Sulphur will condensate at the surface and this will lead to corrosion and therefore to a mechanical damage.

To preventing condensation at the RTO inlet, the control circuit determines the raw gas temperature at the inlet of the RTO by taking a small portion of the hot air from the combustion chamber and leading it back in the raw gas line via the preheating control valve 5150-AOV-710.

RTO mode START and STANDBY:

During mode START of the RTO, at a combustion chamber temperature of 650°C, the preheating control will be released and the hot air from the combustion chamber is added to the ambient air and purge air stream, which is maintained by the preheating blower B5153 via the ambient air valve 5150-AOV100 and purge air valve AOV-391, before it enters the raw gas duct.

To prevent a too fast temperature increase, the controller heats up the raw gas temperature via a ramp function of the controller. The ramp setpoint value (setpoint 2 of the controller) starts at actual temperature of 5155-TT-201 and increases its value slowly up to the desired preheating temperature, given by setpoint 1. After reaching setpoint 1 the controller switches to normal PID controller operation.

RTO mode OPERATION and BAKEOUT OPERATION:

The ambient air valve 5150-AOV100 is in control mode in RTO mode OPERATION and limits the temperature in the preheating duct by adding cold ambient air. The hot air from the combustion chamber via 5150-AOV-710, which is used for preheating the raw gas, gets mixed with this cold ambient air and the purge air before it enters the raw gas duct.

The preheating controller is in normal PID controller operation.

If limit values are exceeded, alarms and corresponding actions will be activated.

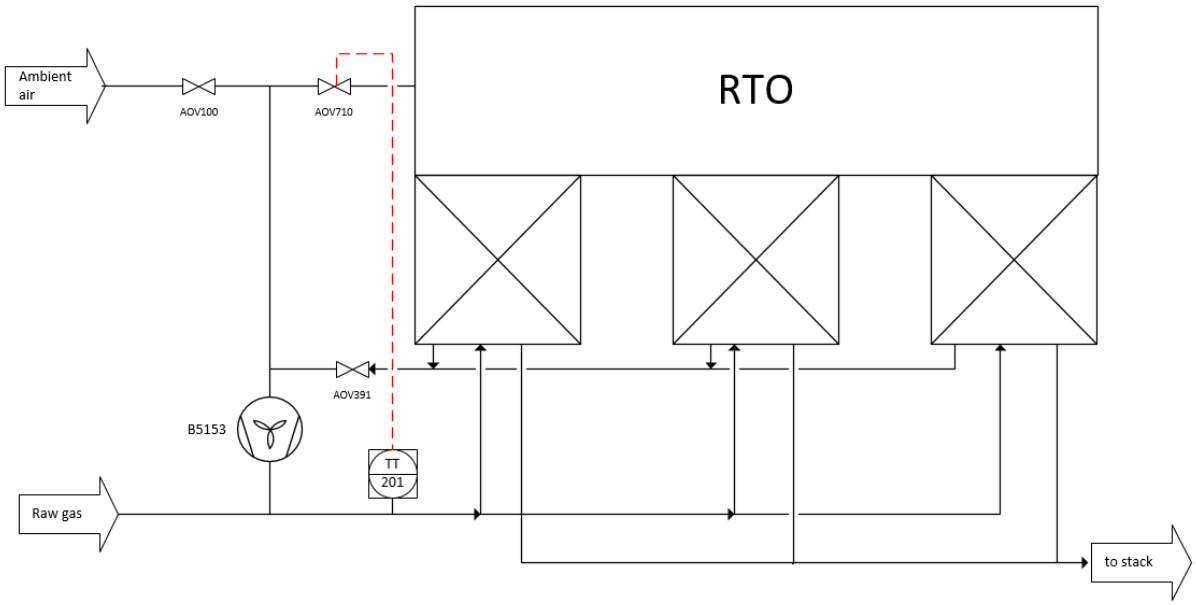

Figure: Temperature control circuit for raw gas preheating

4.3.5 Temperature control circuit for cooling of preheating system

- *Setpoint:* Temperature value in °C of preheating stream and manual valve position, set at HMI
- Process variable: Preheating stream temperature – 5155-TI-391
- Controller output: Preheating control valve – 5150-AOV100
- Controller type: PID controller

Description:

The preheating stream temperature at the outlet of the preheating blower B-5153 is monitored by a temperature sensor -5155-TI-391.

To prevent excessively high temperatures in the preheating pipe system, the control circuit determines the temperature by controlling the amount of cold ambient air via the ambient air control valve 5150-AOV-100.

If limit values are exceeded, alarms and corresponding actions are activated.

RTO mode START and STANDBY:

The ambient air control valve 5150-AOV-100 is open with a manual value (MV1), no control action.

RTO mode OPERATION and BAKEOUT OPERATION:

The ambient air control valve 5150-AOV-100 is released and active with setpoint 1 (SP1) in PID control mode and limits the temperature in the preheating duct.

In case the temperature at 5155-TI-391 exceeds the H alarm limit, the valve 5150-AOV-710 will be closed by an interlock (alarm with automatic reset)

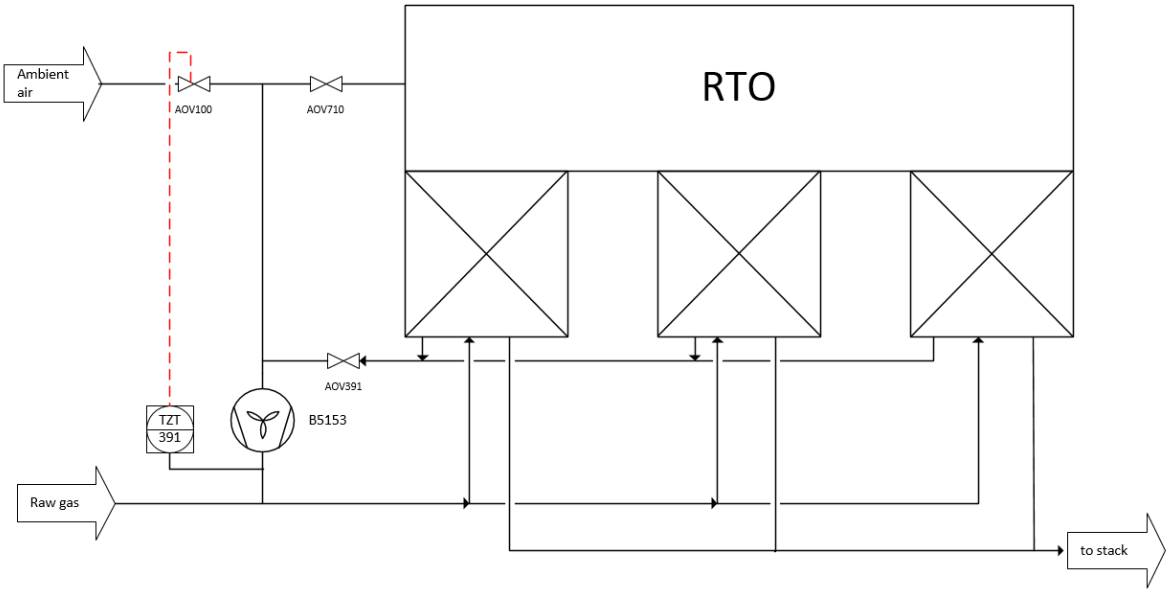

Figure: Temperature control circuit for cooling of preheating duct

4.3.6 Pressure control circuit for preheating system

- *Setpoint:* Pressure value in mbar in preheating duct and manual speed value, set at HMI
- *Process variable*: Preheating pressure – 5150-PIT-390
- *Controller output*: Speed control of Preheating blower – B-5153 via frequency converter
- Controller type: PID controller

Description:

RTO mode OPERATION and BAKEOUT OPERATION:

The negative pressure in the preheating duct is monitored by a pressure transmitter 5150-PIT-390.

The hot stream in the preheating duct, which is mixed with the raw gas for preheating, consists of three different air streams:

- Hot air from the combustion chamber via 5150-AOV-710
- Purge air from the RTO purge lines
- Ambient air via 5150-AOV-100 for limiting the temperature in the preheating duct

The air via 5150-AOV-710 and 5150-AOV-100 is variating, depending on the control action. The flow in the RTO purge lines should be stable, this is ensured by using the preheating blower B-5153 to keep the pressure in the preheating duct 5150-PIT-390 constant on a negative value.

The value of the pressure transmitter 5150-PIT-390 is used as the process variable for the blower controller. The setpoint for this control loop is a negative pressure value, set at the controller pop-up at the HMI. The controller sends his control value to a frequency converter which changes the speed of the blower B-5153 to reach the given setpoint value.

If limit values are exceeded, alarms and corresponding actions are activated.

RTO mode START and STANDBY:

The blower B-5153 is in operation with a fixed speed, set by manual value 1 (MV1) and used to generate the necessary ambient air flow through the RTO to heat up the system and for mode STANDBY.

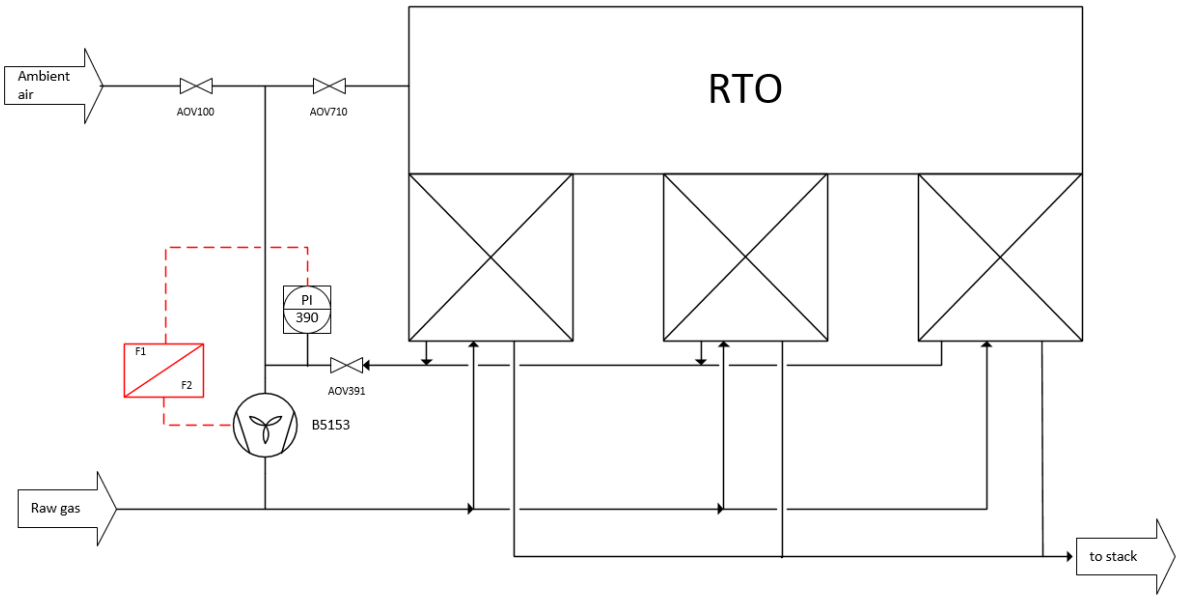

Figure: Pressure control circuit for pressure in preheating duct

4.3.7 Temperature control circuit for combustion chamber (E-Heater)

- *Setpoint: Combustion chamber* temperature value in °C, set at HMI
- *Process variable*: Calculated average combustion chamber temperature 5150-TI-300
- *Controller output*: Control of Electrical heater power – H5150 via Thyristor power controller
- Controller type: PID controller

Description:

The average temperature 5150-TI-300 is calculated with two independent temperature sensors 5150-TT-330/350.

This control circuit determines the combustion chamber temperature 5150-TI-300 of the RTO by controlling the power of the electrical heater H5150 during the heat up process and during modes STANDBY and OPERATION.

The setpoint for this control loop is a temperature value for the combustion chamber, set at the controller pop-up at the HMI. The controller sends his control value to a Thyristor power controller which controls the power of the electrical heater H5150.

In case the combustion chamber temperature rises above the setpoint 1 (SP1) and exceeds a defined limit (set with parameter “combustion chamber limit 2” at the HMI) the heater will be switched off. The heater starts automatically again, if the combustion chamber temperature falls below the “combustion chamber limit 2” (considering a hysteresis).

If limit values are exceeded, alarms and corresponding actions are activated.

RTO mode START and STANDBY:

To avoid cracks in the heat exchanger ceramic and in the RTO combustion chamber, a temperature ramp setpoint (SP2) of approx. 2°C/minute is used to slowly heat up the RTO system, during start up mode (heating up mode). The ramp setpoint starts at the actual combustion chamber temperature and if the desired combustion chamber temperature (set with parameter “combustion chamber limit 1” at the HMI) is reached, the heat up process is finished and the start-up sequence changes to mode STANDBY.

In standby mode the controller is in normal PID mode with setpoint 1 (SP1) and controls the combustion chamber temperature

RTO mode OPERATION and BAKEOUT OPERATION:

In RTO mode OPERATION the controller is in normal PID mode with setpoint 1 (SP1) and controls the combustion chamber temperature.

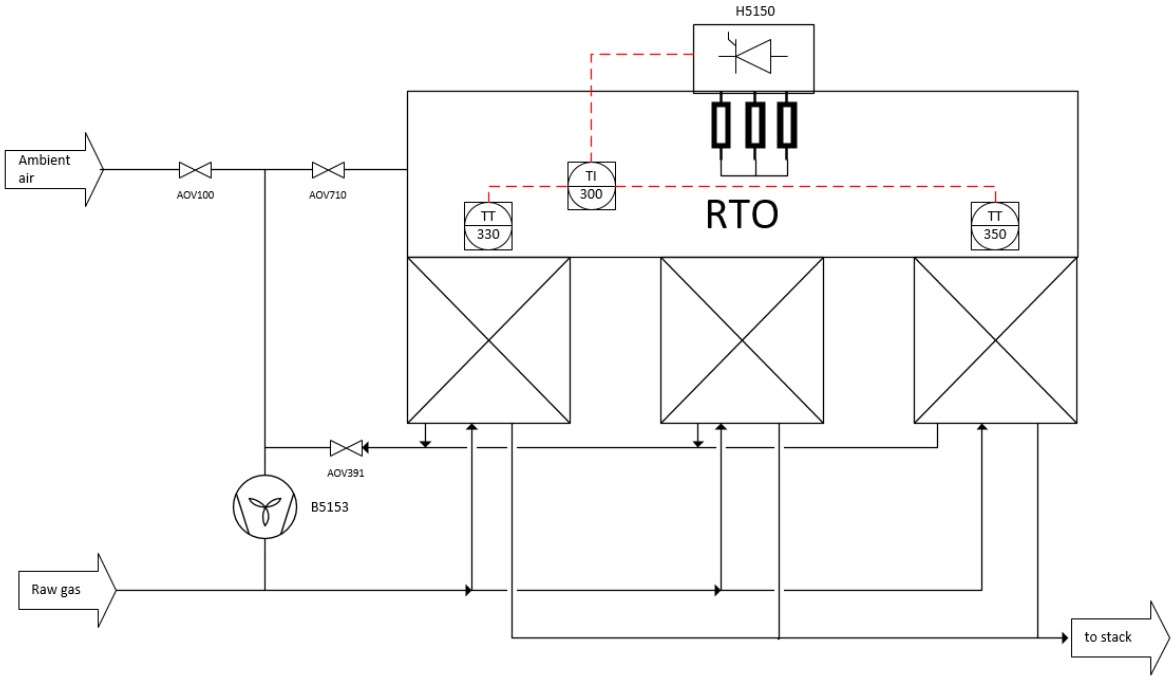

Figure: Temperate control circuit for combustion chamber (E-heater)

4.3.8 Temperature control circuit for combustion chamber (Hot bypass)

- *Setpoint 1:* Combustion chamber temperature value in °C, set at HMI
- *Setpoint 2:* Clean gas temperature in stack value in °C, set at HMI
- *Process variable 1*: Calculated average combustion chamber temperature 5150-TI-300
- *Process variable 2*: Clean gas temperature in stack 5150-TI-501
- *Controller output*: Hot bypass control valve 5150-AOV-700
- *Controller type:* P- and PID- controller

Description:

RTO mode STANDBY, OPERATION and BAKEOUT OPERATION:

In case of autothermal RTO operation with a high VOC load in the raw gas stream, the combustion chamber temperature rises caused by the heat out of the combustion of the VOCs.

If the combustion chamber temperature exceeds the “combustion chamber limit 2”, the electrical heater, which normally controls the combustion chamber temperature, will be switched off.

To limit the energy in the combustion chamber and to be able to control the temperature, also in autothermal mode, a “Hot bypass” is installed, which connects the combustion chamber with the RTO stack via the hot bypass valve 5150-AOV-700.

The calculated average combustion chamber temperature 5150-TI-300 is used as the process value for this control loop. With controlling the hot bypass valve 5150-AOV-700, a small amount of hot air is released direct to the stack which has an immediate cooling effect in the combustion chamber.

The hot bypass controller acts as a P-controller in this RTO modes and the temperature setpoint (SP1) is higher than the set point of the electrical heater.

RTO mode COOLDOWN:

The hot bypass is also used in the cooldown mode, to release as much hot air as possible into the stack to speed up the cooldown of the RTO. In this mode the process value for the controller is the temperature sensor in the stack 5157-TT501.

The hot bypass controller acts as a PID-controller in this RTO mode and the temperature setpoint (SP2) is set at the HMI screen, but limited with the maximum allowed temperature in the stack.

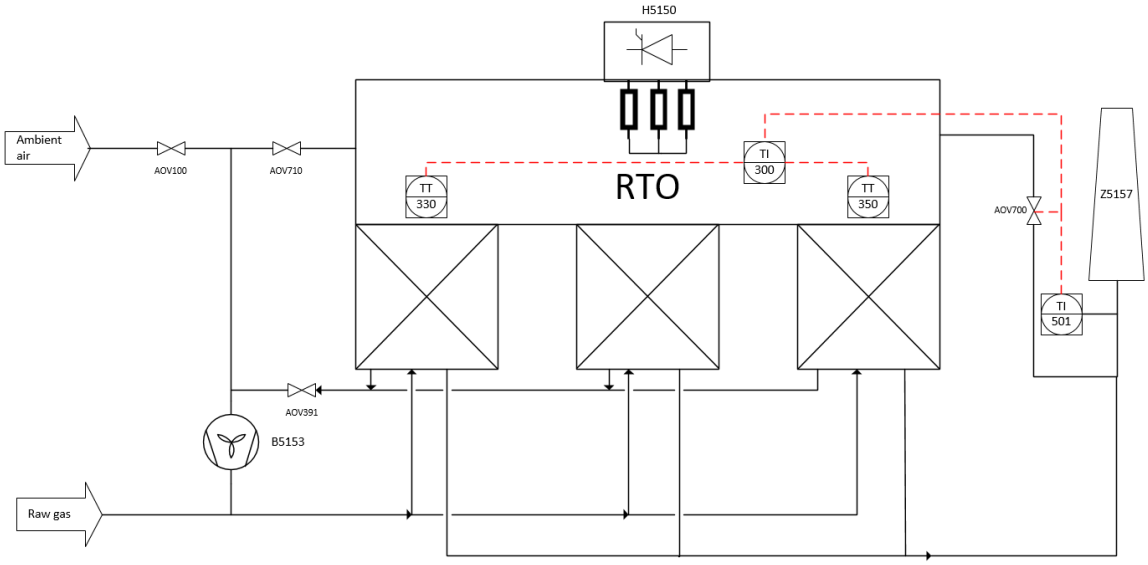

Figure: Temperature control circuit for combustion chamber (Hot bypass)

5 OPERATION

5.1 Step sequences

An automatic step sequence will change the System condition step by step in order to reach the requested mode. The initiation of the step sequence is made as an operation request from an operator via the HMI. Each step has its step action(s), where an output (valve, fan, ...) is set as soon as the ID step is activated. Also, an alarm time can be started if required. An ID delay time is also started, when it is elapsed it is one of the conditions for enabling the next step. If all conditions for the next steps are OK, the step sequence will move to the next step.

5.2 Modes of operation

The following chapter covers the different operation modes of the system. There is an introductory explanation for each mode as well as a detailed description of all the underlying processes.

Please find detailed information about the operation of the VOXcube 3-075 in the operation manual.

- Mode STOP Plant is switched off
- Mode START Plant is heating up
- Mode STANDBY Plant is ready for takeover of waste gas
- Mode STBY-OPER Plant switch from ambient air to waste gas
- Mode OPERATION Plant takes over waste gas
- Mode COOL DOWN Plant is cooling down
- Mode OPER-STBY Plant switch back from raw gas connection to ambient air
- Mode STBY-STOP Plant switch back to switched off
- Mode BAKEOUT Plant cleaning heat exchanger of the RTO

5.2.1 Stop mode

The system can go to STOP in two ways, via QUICKSTOP alarm or via command STOP.

- STOP means the RTO is in stop and out of operation. When the running plant gets the STOP signal, the
- RTO system will shut down within defined steps:
  - RTO is performing STOP sequence and is shut down

- QUICKSTOP is a fast stop where the RTO is switched off immediately without following the STOP procedure

In the mode STOP the system is switched off:

- All actuators are in defined position.
- The preheating blower is switched off.
- The electrical heater is off.
- The raw gas valves 5150-AOV-200 and AOV201 are closed and separate the RTO system from the raw gas.
- The bypass valve 5166-AOV-210 is open.
- The blower B5154 is active, as long as the combustion chamber temperature is >400°C

The plant is switched off by pressing the „STOP“ button on the HMI or switching the AUTOMATIC – 0 – SERVICE switch on the control cabinet to 0 - position.

The switch position 0 or SERVICE is used for maintenance actions on the plant!

5.2.2 Start mode

During the start-up process, the system is heated up until the operation temperature is reached. After that, the system remains in this mode.

In this mode the following processes are executed:

1. The ambient air valve opens.
2. The preheating blower starts at a fixed speed.
3. The main valve cycle starts and generate the necessary airflow for heat up via the ambient air valve.
4. The electrical heater starts, and the system starts heating up with a ramping setpoint.
5. The time needed for reaching the operation temperature (combustion chamber temperature limit 1) varies, depending on the combustion chamber temperature while starting the heater and the heat-up ramp.
6. The ceramic heat exchangers are heated up uniformly until they reach the specified temperature.
7. During heat up, if the combustion chamber rises above 650°C, the preheating of valve box and cones is activated.
8. As soon as the combustion chamber temperature limit 1 is reached, the combustion chamber control switches from the heat-up ramp to the constant normal operation set value (set point 1).
   In case the combustion chamber temperature limit 1 is not reached within a certain time period, an alarm is activated.
9. After successful raw gas preheating and a stabilization time the system switches to standby mode.

NOTICE!

Risk of environmental damage from untreated raw gas due to a lacking raw gas valve!

- Make sure that no raw gas can enter the system during the start-up process.

5.2.3 Standby mode

When the system is in standby mode, it operates with ambient air (25 - 30 % of the nominal flow). The combustion chamber temperature is kept constant, the system is on hold.

- The ambient air valve is open.
- The preheating blower runs at a fixed speed.
- The main valve cycle is active.
- The electrical heater is active.
- The raw gas valves are still closed.
- The raw gas preheating is active.
- The hot bypass controller is active.

5.2.4 Operation mode

The system switches to operation mode and takes over the raw gas from the customer's process according to the individual process design. The raw gas is cleaned in the hot combustion chamber of the RTO.

In RTO mode OPERATION, the following processes are executed:

1. The raw gas valves are open.
2. Combustion chamber temperature controller for the electrical heater is active
3. Combustion chamber temperature controller for the hot bypass valve is active
4. The dilution air controller for LEL and O2 is active.
5. The preheating temperature controller of the raw gas is active.
6. The ambient air valve is in control mode and limiting the preheating air temperature.
7. The preheating blower is switched to automatic mode and controlling the pressure in the preheating pipe.
8. The raw gas LEL controller is active.
9. Bypass valve to emergency stack is closed

5.2.5 Switching from operation to standby mode

While the system switches from operation to standby mode, the following processes are executed:

1. The raw gas valves are closing.
2. Combustion chamber temperature controller for the electrical heater is active
3. Combustion chamber temperature controller for the hot bypass valve is active
4. The dilution air controller for LEL and O2 stops.
5. The preheating temperature controller of the raw gas is active.
6. The ambient air valve opens.
7. The preheating blower is switched to fixed speed
8. Bypass valve to emergency stack opens

5.2.6 Switching from standby to stop mode

While the system switches from standby to stop mode, the following processes are executed:

1 The electrical heater is switched off.
2 The system is purged with ambient air.
3 The hot bypass controller is off.
4 The preheating is off.
5 The preheating blower stops.
6 The ambient air valve closes.
7 The main valve cycle stops.

5.2.7 Cooldown mode

The cooldown mode is used for a quick cooldown of the system. It is especially useful for maintenance works and inspections. The cooldown can only be started from stop mode; the following processes are executed:

1 The ambient air valve opens.
2 The preheating blower is operated at a fixed speed (30 - 50 % of the nominal flow). This can be adjusted manually if necessary (see CTP system documentation, chapter "parameter list").
3 The main valve cycle is activated.
4 The hot bypass control is activated. The control valve regulates the stack temperature. So, the maximum heat is taken out of the combustion chamber.

The process remains active until the combustion chamber temperature has cooled down to 30 - 40 °C. Then the system switches to stop mode automatically.

5.3 Heat up processes

5.3.1 Standard heat up process

In start mode, the system is heated up straight to the standby temperature.

Heat up curve

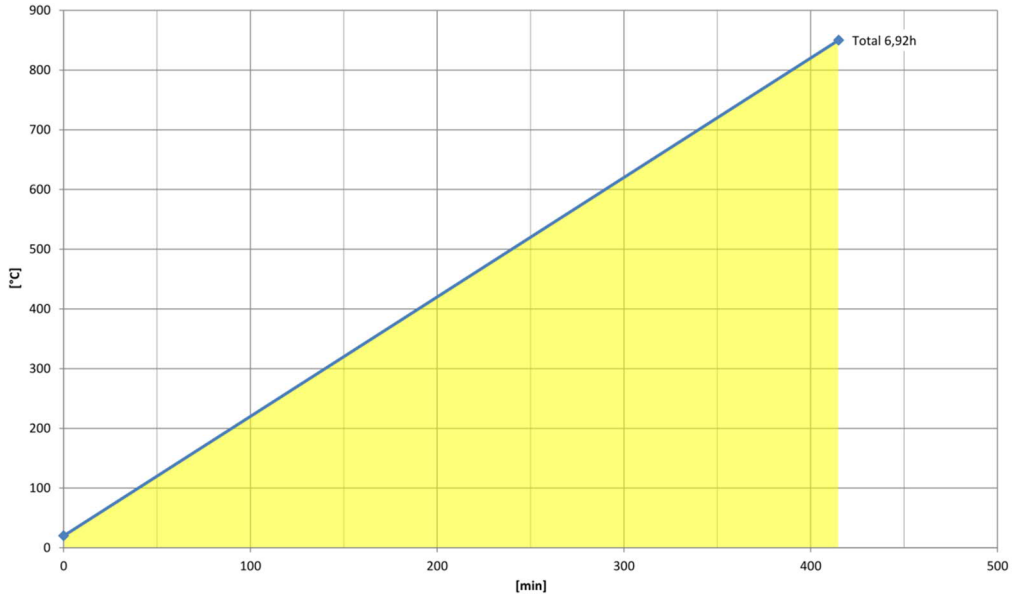

Figure: Heat up process in start mode

Figure explanation	Values
Ramp	2 °C/min.
Duration	within ~7 hrs.
Temperature	up to 850 °C

5.3.2 Slow heat up process (wash out ramp)

In certain cases, the system must be heated up in an especially slow procedure. This is

- during the first start-up of the system
- after a cleaning of the combustion chamber
- after the exchange of ceramics, inner insulation etc.

Usually, these procedures and the re-start are executed by CTP.

During the slowed down heat up sequence, the following processes are executed.

1 The combustion chamber is heated up to 100 °C with minimum burner performance via a slow ramp.
2 The 100 °C temperature level is kept constant for a certain time period.
3 After that the combustion chamber is heated up to 250 °C, again via a temperature ramp.
4 Finally, the combustion chamber is heated up to standby temperature via the normal heat up ramp.

Heat up curve

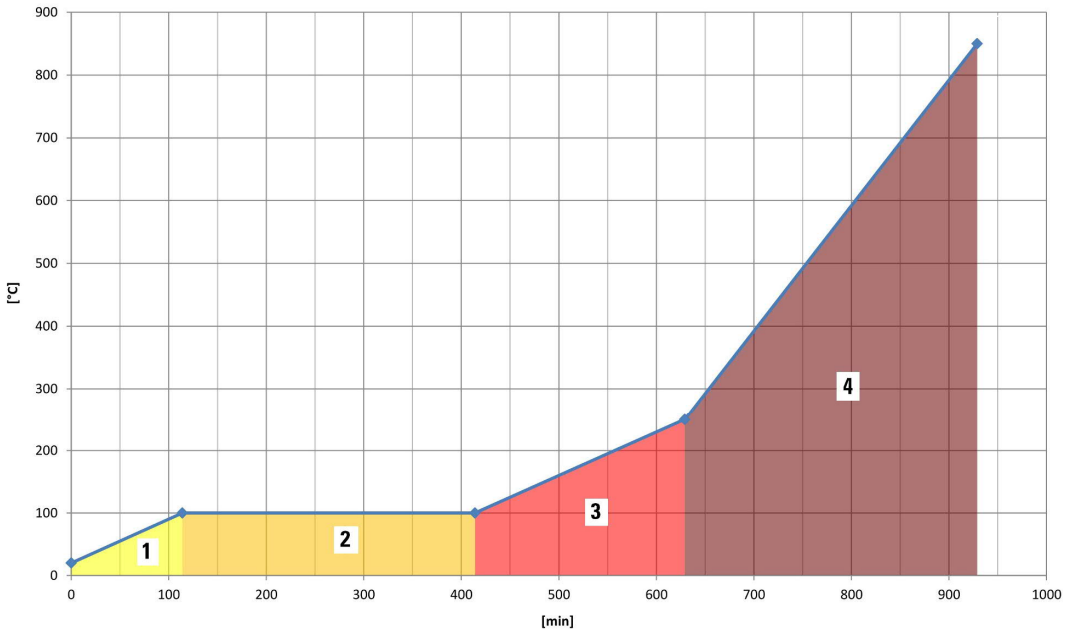

Figure: Slow heat up process via temperature ramps

Figure explanation	Phase 1	Phase 2	Phase 3	Phase 4
Ramp	0.7 °C/min.	none, temperature constant	0.7 °C/min.	2 °C/min.
Duration	2 hrs.	5 hrs.	3-4 hrs.	5 hrs.
Temperature	up to 100 °C	100 °C	up to 250 °C	up to 850 °C

6 APPENDIX

6.1 Operation data

6.1.1 Design Parameters

6.1.1.1 Off-gas sources

- Flowrate:

  4000 -5400 m3/h @ 35°C and 1 ATM
  This corresponds to a maximum of 4800 Nm3/h (@ 0°C and 1 ATM)

- Temperature:

  -20°C – 50°C

- Main components:

Pos.	CAS-Nr.	Name	Formula	
1	74-82-2	Methane	CH_4	< 100 mg/Nm³
2	71-43-2	Benzene	C_6H_6	< 100 mg/Nm³
3	106-97-8	Butane	C_4H_{10}	Lead substance (no butadiene containing)

- Concentrations for design case without mayor gO.1 concentration
  - Average: 3 g/Nm³
  - Maximum design: 6 g/Nm³
  - Peak design: 10 g/Nm³

- Concentrations for upset case with gO.1

  Peak design: 5 g/Nm³ VOC
  whereas
  gO.1 components (T_boiling_point < 150°C) < 1000 mg/Nm³
  Lead substance as defined < 4000 mg/Nm³

- Other components:

  - Content of dust: < 0,1mg/Nm³
  - Sulfur content raw gas
    - Mercaptanes + H_2S < 1 ppm sulfur
    - SO_3 dewpoint 71,2°C -> Raw gas preheating to 90°C

- Dust: < 0,1 mg/Nm³
- O_2-level: between 3 and 21 vol%

6.1.1.2 Design cases

		AVG.	Max.	Peak.
Flow rate (wet condition)	Nm³/h wet	4.800	4.800	4.800
Temperature	°C	20	20	20
Pressure	mbar(g)	-5	-5	-5
Water - H_2O [1]	vol.%	1,8	1,8	1,8
Carbon dioxide - CO_2	vol.% wet	0,0	0,0	0,0
Oxygen - O_2	vol.% wet	20,5	20,5	20,5
Nitrogen – N_2	vol.% wet	77,1	77,1	77,1
Nitrogen monoxide - NO	g/Nm³ wet	0	0	0
Nitrogen dioxide – NO_2	g/Nm³ wet	0	0	0
Nitrous oxide – N_2O	g/Nm³ wet	0	0	0
Sulfur Dioxide – SO_2	g/Nm³ wet	0	0	0
Ammonia – NH_3	g/Nm³ wet	0	0	0
Methane	g/Nm³ wet	0,1	0,1	0,1
Benzene	g/Nm³ wet	0,1	0,1	0,1
Butane	g/Nm³ wet	3,0	6,0	10,0
Nitrogen compounds		none	none	none
Sulphur compounds		as specified in 6.1.1.1		
Halogenated compounds		none	none	none
Silicon compounds		none	none	none
PCDD/PCDF		none	none	none
Dust – inorganic / organic		< 0,1	< 0,1	< 0,1
Aerosols		none	none	none
Zone classification		none	none	none

All values expressed in wet condition and at actual O_2 content.
Normal cubic meter (Nm³) refers to the volume of wet gas at a pressure of 101.325 Pa and 0 °C.

According to EN12753 the maximum VOC concentration in the waste gas entering the RTO via the valve box must never exceed 25% LEL (20% LEL in case of a mass content of aromatic hydrocarbons > 25%). The customer ensures that this level is not exceeded or chooses an appropriate LEL protection system in accordance with CTP (refer to concentration safety package).

[1] 60% saturated at 25 °C and 1.013 mbar(a)

6.1.1.3 Environmental conditions

Temperature	°C	-20 to 35
Relative humidity	%	60 - 80
Wind speed	m/s	n.a.
Seismic zone		n.a.
Altitude	masl	< 100

6.1.2 Performance DATA

Preheating:
At 90°C preheating temperature the autothermal operation at conditions below is at 3,0g VOC at MaxFlow. This means above 3,0g/Nm³ VOC no additional e-heater power is necessary. Operation with -20°C raw gas and -20°C ambient air and 90°C preheating is possible from 0 – 6g/Nm³ VOC.

No Preheating:
In case of no sulfur in the raw gas preheating can be stopped by signal from the customer. In this case autothermal operation is possible with 1,43g/Nm³ VOC, this means above 1,43g/Nm³ no electic heater is necessary.

		Zero VOC Max Flow Min Temp No Preheating	0,5g VOC Max Flow No Preheating	Zero VOC Max Flow Min Temp Preheating	3g VOC Max Flow Preheating	6g VOC Max Flow Preheating	10g VOC Max Flow Preheating
Flow rate (wet condition)	Nm³/h wet	4.800	4.800	4.800	4.800	4.800	4.800
Temperature Raw Gas	°C	15	35	15	35	35	35
Temperature Ambient Air	°C	-20	20	-20	20	20	20
Pressure VRU	mbar(g)	-5	-5	-5	-5	-5	-5
VOC	g/Nm³	0	0,5	0	3	6	10
LEL-Dilution	Nm³/h	0	0	0	0	0	700
Preheating Temp.	°C	n.a.	n.a.	90	90	90	90
Combustion Temp.	°C	850	850	850	850	850	850
Preheating extracted from combustion chamber (included in E-Heater below)	kW	0	0	144	106	106	130
E-Heater	kW	74	39	226	0	0	0
P-Main Fan	kW	6,2	6,7	6,7	7,2	7,2	11,4
P-Purge-Preheat Fan	kW	0,9	0,9	4,0	3,1	3,1	4,4
Stack Temp.	°C	43	62	111	110	205	297

Electricity RTO Operation 5,5 kW

Compressed Air	12 Nm3/h (including 2x2 Nm3/ for two FID's)
Start-Up RTO	150 kW for 5h start-up time

6.2 CTP contacts

Field of responsibility	Email address
Mechanical & electrical design	office@ctp.at
Maintenance & service	service@ctp.at

6.3 CTP type plate

The CTP type plate contains the following information:

- Manufacturer
- Address
- System type
- Project number
- Flow
- Year of construction
- CE marking

The CTP type plate is located on the left side of the valve box.

6.4 Certificate of receipt

The personnel confirm with their signature that they have received the relevant parts of the CTP user manual.

Date	Name	Signature

6.5 Room for notes