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High Temperature Pre-Heating of Steam

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Abstract

The development of regenerators for the pre-heating of combustion air has made an enormous progress in the last years, regarding ecology and economics. Pre-heating of combustion air to temperatures up to 1400°C is feasible without problems. Depending on the industrial application, different types of regenerators are used. The PulsReg®, PulsReg®-Central and EcoReg® are the most frequently assigned regenerators.

The advancement of the most different engineering processes requires an optimization of the integrated components also. In Japan different systems are under development and partly already in application for the production of clean low BTU gas out of different kinds of waste. The STAR MEET system (**S**tream/**A**ir **R**eforming type **M**ultistaged **E**nthalpy **E**xtraction **T**echnology) produces a clean low BTU gas and this can be utilized as a fuel for power and heat generation. The waste is fed directly into pyrolysis plants without pre-treatment. The necessary thermal energy for the pyrolysis and gasification process is obtained by preheated air. During the pyrolysis or gasification process inevitably tar and soot is produced. An air/steam-mixture with a temperature up to 1000°C is injected into a Reformer. The tar and soot reacts with the high temperature steam to Carbon Monoxide and Hydrogen.



As a result of this endothermic reaction the heating value of the reformer gas is increased. The resulting gas can be cooled down and the dust can be separated in a dry filter without any problems.

The high temperature of the air/steam mixture is obtained by the rotating regenerator EcoReg®. The air and steam is led independently into the regenerator and reaches pre-heating temperatures of up to 1000°C. The operating temperature for the regenerator is achieved by a burner. This burner works with a part of the new produced reformer gas as fuel. The exhaust gas temperature behind the EcoReg® is clearly below 300°C.

The HyPR-MEET (**H**ydrogen **P**roduction type **M**ulti-**S**taged **E**nthalpy **E**xtraction **T**echnology) System needs steam which is heated up to 1300°C. This will be realized by the further development of a high temperature heat exchanger – the rotating regenerator EcoReg®.

The advancements of the EcoReg® in the process of the preliminary high temperature heating of steam are described within this paper.

Introduction

Developments of regenerators for high temperature pre-heating of air have made a significant progress in recent years. Air-preheat levels of up to 1400°C with waste gas inlet temperatures of up to 1600°C are now technically achievable and have already been implemented. The various and most widely used types of regenerators are examined in this paper for their function and use.

In Japan [1] tremendous efforts have been done in the development of plants for waste to energy. The STAR-MEET (**S**team/**A**ir **R**eforming type **M**ultistaged **E**nthalpy **E**xtraction **T**echnology) System is successfully tested and in operation. The HyPR-MEET (**H**ydrogen **P**roduction type **M**ulti-**S**taged **E**nthalpy **E**xtraction **T**echnology) System is still under development and will be in operation at the end of this year 2005.

In these systems, different kinds of solid waste are pyrolyzed in a gasifier and the pyrolysis gas is reformed by high temperature steam and air mixture. The reformed gas is purified to become a low BTU fuel gas, which can be utilized for power and heat generation.

The further development of the rotating regenerator for the application in the STAR-MEET and HyPR-MEET System to preheat steam, respectively a mixture of air and steam, is also described.

Regenerative Heat Exchanger

Today different designs of regenerators exist. The designs are developed from different applications in industrial firing systems. The most important regenerative heat exchanger is described in the next chapter [2].

The PulsReg®-Regenerator (Figure 1) is the classical regenerator/burner design consisting of 2 regenerators with two assigned specially developed burner heads. One regenerator is heated up by the waste gas during the second regenerator is cooled down by the cold combustion air. If the heating of the regenerator is sufficient, the direction of the flow inside the regenerators changes and the regenerator which was heated with exhaust gas will be cooled now with air. The regenerator which was cooled by air will be heated now with exhaust gas. The changing flow direction in the regenerators is done by valves. The operation of the assigned burners is switched accordingly.

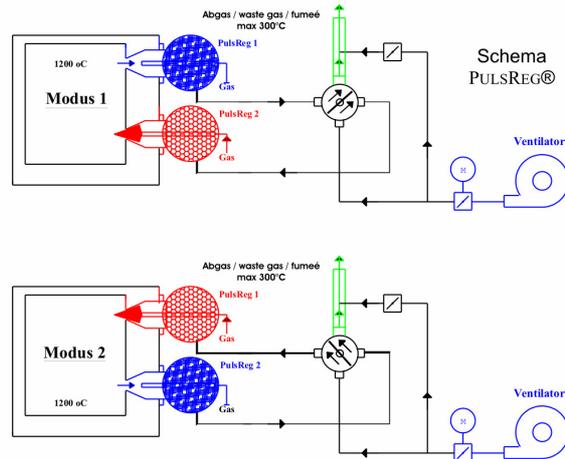


Figure 1: RI-Flow Sheet PulsReg®

This regenerator is a container with a refractory lining and contains a heat storage filling.

The PulsReg®-Central Regenerator System (Figure 2) consists of two regenerators with any number of burners. The exhaust gas flow and the hot-air flow have separate pipes. The exhaust gas flow is not sucked off through the burner and the burners are not assigned to any regenerator. The exhaust gas is supplied to the regenerators by a separate pipe from the furnace. The regenerators change cyclic in normal operation.

The number of burners is arbitrary for independent heating zones = PulsReg®-Central.

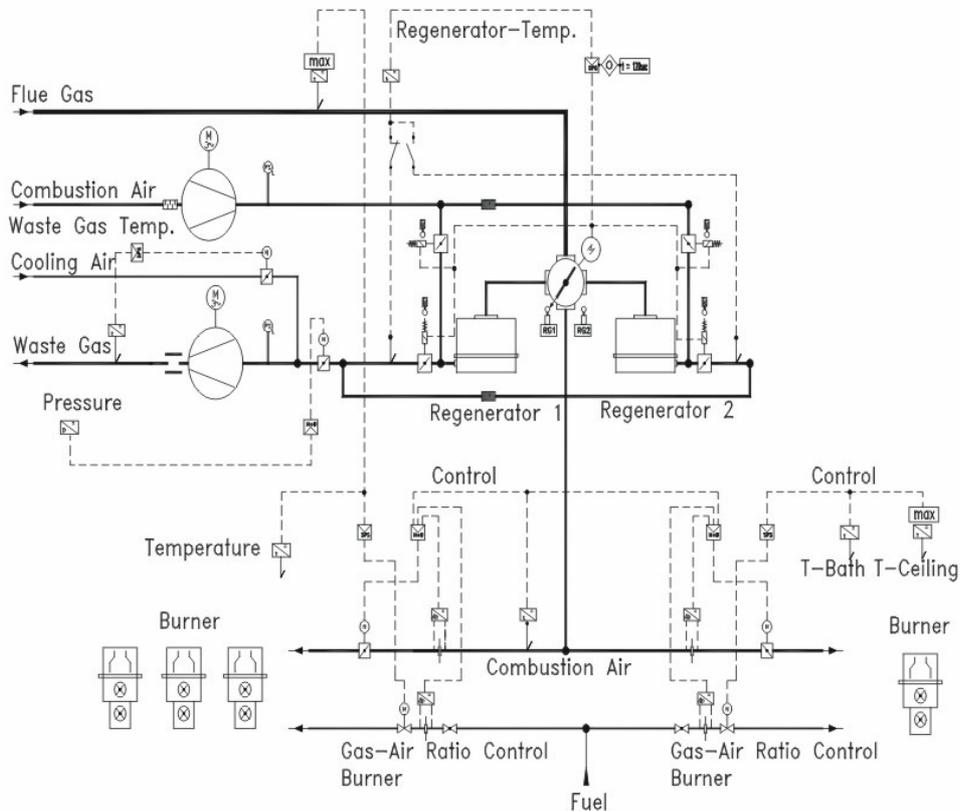


Figure 2: RI-Flow Sheet PulsReg®-Central

The rotating regenerator type EcoReg® (Figure 3) is a regenerator for large achievements and any number of burners. The burners are not assigned to the regenerator and the exhaust gas flow does not pass the burner. An organization of independent and continuously regulated heating zones is possible. The exhaust gas can be taken from any arbitrary place of the furnace and is supplied in a separate pipe to the rotating bed regenerator. The complete exhaust gas flow from the furnace is led to the regenerator.

The application of the EcoReg® takes place in high performance plants and large furnaces. The regenerator is beside the furnace, sucks the exhaust gas off completely and supplies any number of burners with hot combustion air continuously. A central heat recovery from several furnaces is also possible. The exhaust gas flow behind the EcoReg® can be supplied directly to a filter system without additional cooling. The exhaust gas temperature is clearly below 300°C.

In principle the two regenerators of a classical regenerator system are summarized physically in one rotating regenerator.

The bottom part and upper part of the regenerator are fixed. The bottom and the upper part have in each case two chambers, flown by the cold/hot exhaust gas and/or the cold/hot combustion air. The middle section is rotating between the lower and upper part and is divided into several segments.

The sealing of the center section is made by sealing strips from steel and/or ceramic. The hot flue gas passes the segmented heat exchanger filling while the middle part is rotating. It takes the heat energy from the exhaust gas and stores it in the heat exchanger filling. During the further rotation of the middle part the hot segments come into the range of the cold combustion air. The filling stores the heat energy from the exhaust gas. The temperature in these segments decreases and continues turning into the hot part again, where a new heating takes place.

The efficiency of the heat recovery is in average more than 80 % related to the inlet temperature of the flue gas. The flue gas temperature usually amounts to 1200°C. As a result an average combustion air temperature of approximately 1000°C is achieved. In the high temperature version, inlet temperatures of about 1600 °C are realized. The leaving exhaust gases out of the EcoReg® -Regenerator have outlet temperature levels between 150°C to 220°C.

Advantages of the EcoReg® are as follows:

- the setting of a constant pressure by a continuous operation of the regenerator
- any setting of pressure
- the volume flow out of the EcoReg® to the burners can be set independently
- the complete removal by suction of the exhaust gas over the EcoReg®
- constant flue gas temperature to the filter system
- variable setting of the output.

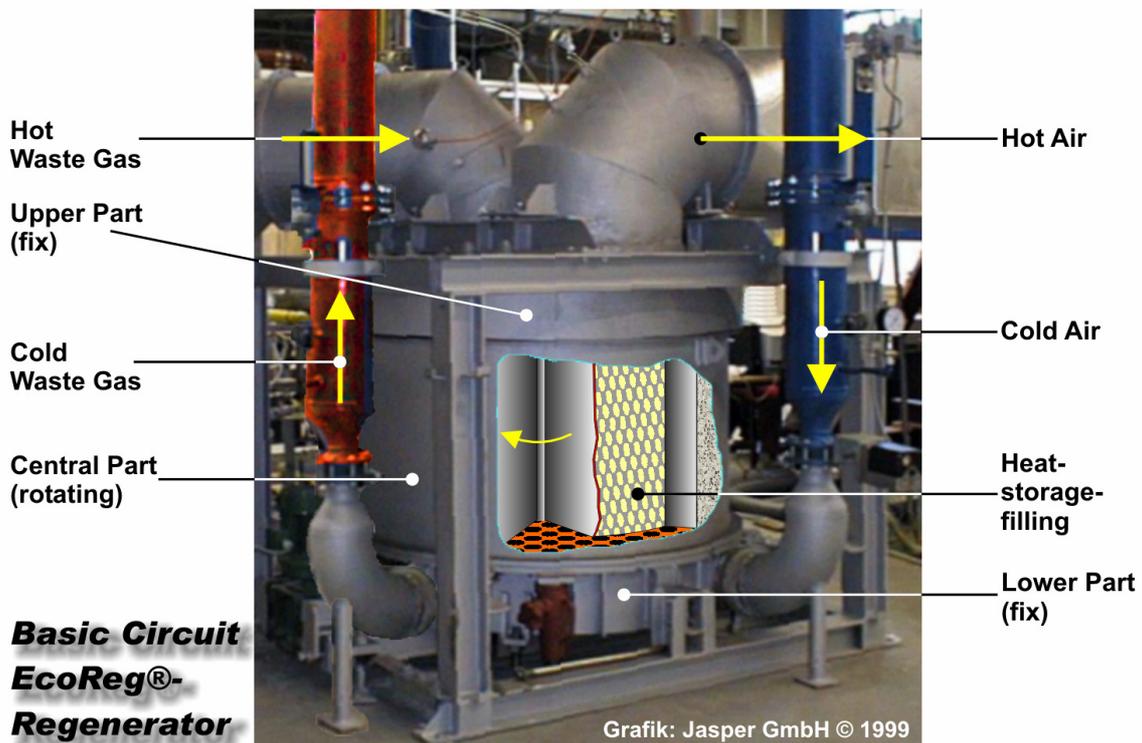
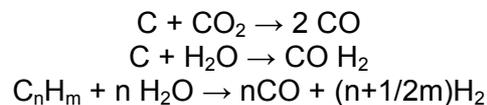


Figure 3: EcoReg®-Regenerator

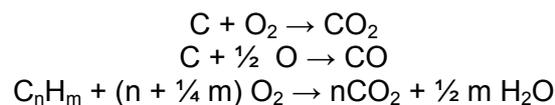
The EcoReg®-Regenerator for the Pre-Heating of Steam

The application of the EcoReg®-Regenerator for the pre-heating of steam takes place in the above mentioned The STAR-MEET (**S**tream/**A**ir **R**eforming type **M**ultistaged **E**nthalpy **E**xtraction **T**echnology) System and HyPR-MEET (**H**ydrogen **P**roduction type **M**ulti-**S**taged **E**nthalpy **E**xtraction **T**echnology) System [1].

In the Star-Meet System (Figure 4) solid wastes are pyrolyzed. The pyrolysis gas contains tar and soot components and is introduced in a reformer where the gas reacts with steam and is decomposed into CO_2 and H_2 by following chemical reactions:



By using high temperature air and steam the kind of the chemical reactions can be shifted from exothermic to endothermic, increasing the heating value of the low BTU fuel as a result.



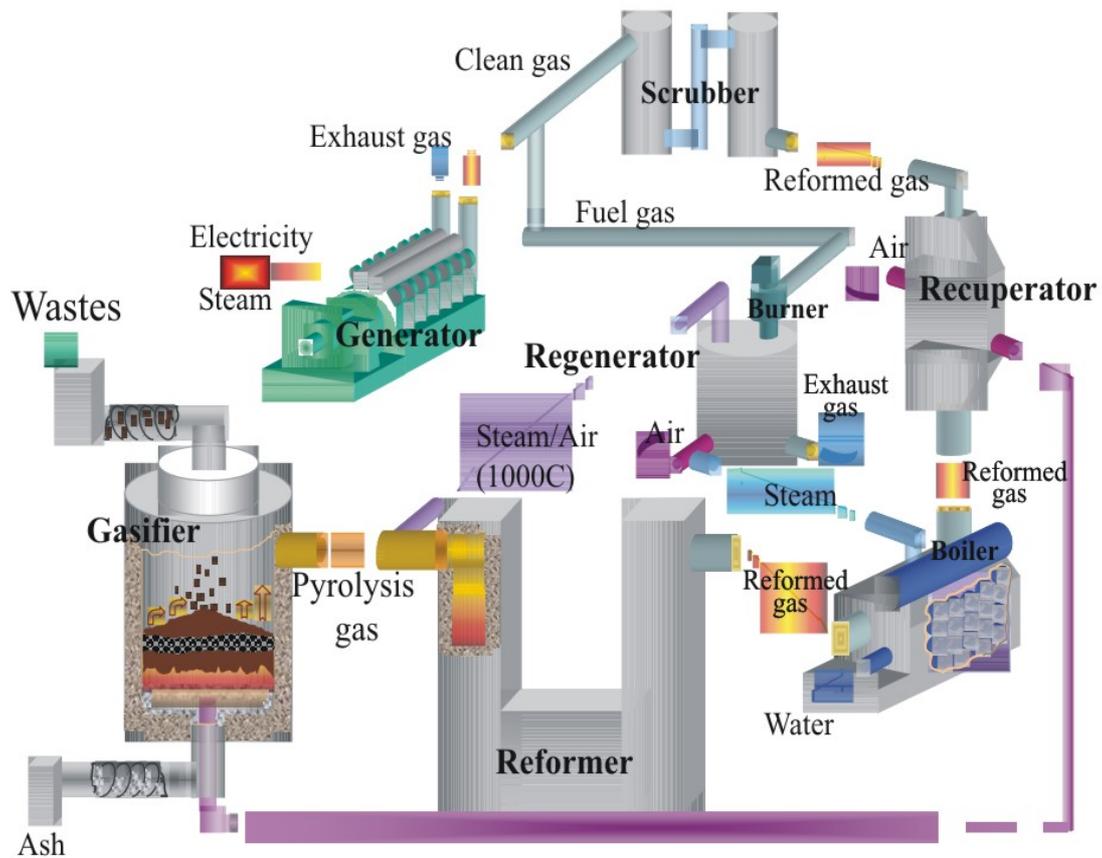
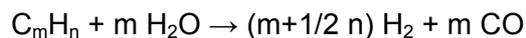


Figure 4: The EcoReg®-Regenerator within the STAR-MEET-System [1]

In the HyPR-Meet System (Figure 5) the high temperature steam will be supplied in the bottom of a gasifier. The solid waste inside the gasifier will be decomposed to a pyrolysis gas and char. This gas is led to a reformer. The tar content in the gas is reformed by steam and decomposes to H_2 .



The high temperature steam will be provided by a regenerative rotating heat exchanger – the EcoReg® (Figure 6). A volume flow of hot combustion gas comes from top into the rotating EcoReg®. The honeycombs in the rotating middle part are heated up and the combustion gas leaves the Regenerator with temperature clearly below of 300°C. The preheated steam comes up from the bottom into the Regenerator with a temperature of 100°C and is heated up by the hot honeycombs. The steam leaves the EcoReg® with a temperature up to 1400°C.

The reforming reaction is guaranteed by the production of high temperature steam. The heat exchanger is one of the key-systems for a functional STAR-MEET or HyPR-MEET System.

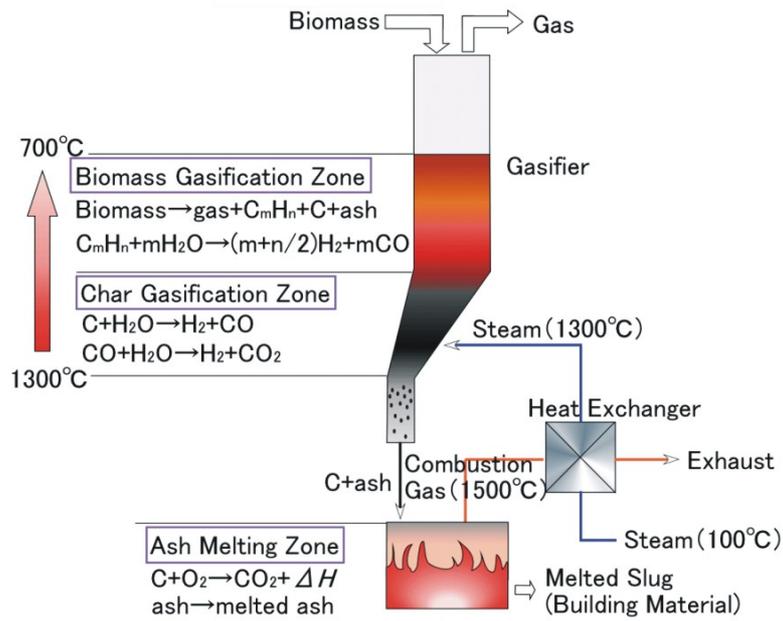


Figure 5: The EcoReg®-Regenerator within the HyPR-MEET-System [1]

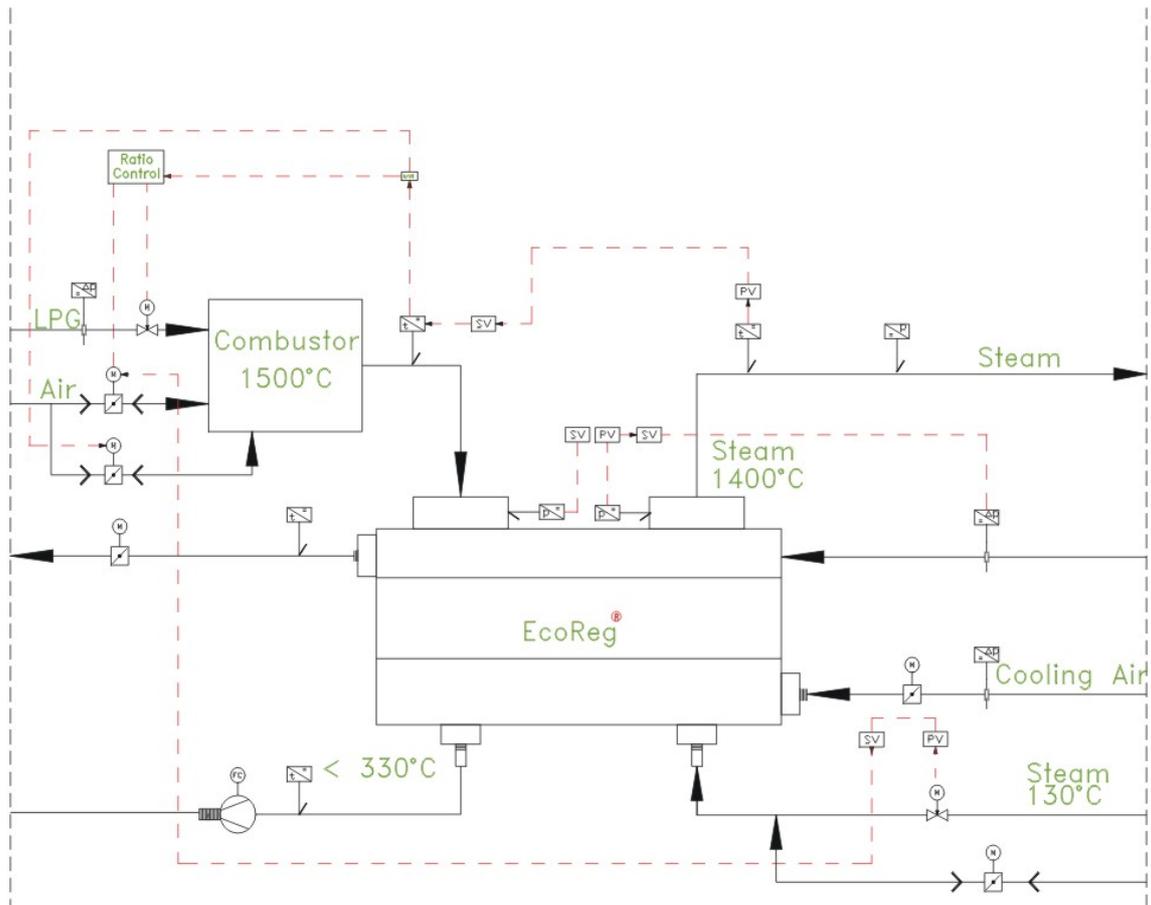


Figure 6: RI-Flow Sheet of the EcoReg®-Regenerator

First Results

Table 1 shows first results of the heat exchanger operation. High temperature steam and a mixture of steam and air is produced by the rotating Regenerator EcoReg® during the heat exchange process with combustion gas which is produced from a small part of the reformed gas.

Table 1: First Results of the heat exchange (Values in °C)

| | First Test | | Test | | Test | |
|--------------|------------|-------------|---------|-------------|---------|-------------|
| | Hot Gas | Air + Steam | Hot Gas | Air + Steam | Hot Gas | Air + Steam |
| Inlet Temp. | 850 | 100 | 920 | 100 | 910 | 100 |
| Outlet Temp. | 160 | 570 | 170 | 680 | 180 | 670 |

The waste gas temperature is clearly below 200°C. The pre-heating of the steam and air/steam mixture reaches 700°C. In the near future the efficiency will be optimised to reach a heat exchange ratio of about 90%. This is an usual efficiency for heat exchange in this type of regenerator.

Summary

In this paper the most frequently assigned regenerators PulsReg®, PulsReg®-Central and EcoReg® for the preheating of air are described. In special waste to energy plants (STAR-MEET and HyPR-MEET) it is necessary to provide high temperature steam for the reforming and gasification process. This is be done by the rotating regenerator type EcoReg®. To meet the requirements for this application a further development concerning the material and control is necessary. The first regenerator is successfully implemented in the STAR-MEET System. Next runs need an optimisation of the regenerator to reach an efficiency up to 90%, which is usual for the heat exchange in this regenerator type.

An actual project is the implementing of EcoReg® in the HyPR-Meet System. This regenerator is the high temperature version. The inlet temperature of the combustion gas is up to 1500°C while the pre-heating of steam reaches 1400°C. The exhaust gas temperature behind the EcoReg® is between 150°C to 220°C and needs no further cooling on the way to the filter system.

Reference

- [1] Yoshikawa, K.: R&D and Commercialization of Distributes Power and Hydrogen Generation from Solid Wastes using High Temperature Air and Steam, 6th International Symposium on High Temperature Air Combustion and Gasification, Essen 2005
- [2] Henning, B.; Klatecki, P.; Jasper, R.: Optimierte Regeneratortechnologie an industriellen Feuerungssystemen, Gaswärme International 06/2005, Vulkan Verlag Essen