ECN-RX--05-184

# The TREC-module: integration of tar reduction and high-temperature filtration

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*Published at 14th European Biomass Conference & Exhibition,*

*Paris, France, 17-21 October 2005*

| Revisions | |
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| A | |
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| Checked/Approved/Issued by:<br><br>H.J. Veringa | ECN Biomass |

November 2005

# THE TREC-MODULE: INTEGRATION OF TAR REDUCTION AND HIGH-TEMPERATURE FILTRATION

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ABSTRACT: The TREC-reactor (Tar Reduction by Char) is a technology developed and patented by ECN to reduce the tar concentration in product gas leaving a biomass gasifier. This is done by creating sufficient contact time at high temperature between tars and char, which is generally entrained by the gas and shows good catalytic activity for tar destruction. The TREC-reactor is a moving granular bed filter and is designed to operate at low pressure drop. At 900°C operating temperature, the tar concentration can be reduced by 80% and the tar dew point can be reduced from approximately 350°C to 170°C. Furthermore, the TREC functions as a high-temperature filter, which removes over 99% of the particles from the gas.
Keywords: gasification, tar removal, ash

## 1 INTRODUCTION

Most biomass gasification reactors presently on the market, produce a tar containing product gas. The tar concentration depends on the type of gasifier and the operating conditions. A popular type of reactor, the (circulating) fluidised bed, produces approximately 10 $g/m_n^3$ of tar in the product gas. This not only involves several percent of the heating value of the gas, it also gives rise to serious fouling problems. The dew point of these tars is typically 350°C [1,2]. This means that the tars condense on surfaces colder than the mentioned dew point temperature. In practice this leads to serious fouling in the gas cooler.

The removal of tar from product gas is one of the main items in biomass gasification R&D at present. Many different methods are available in various stages of development from research to demonstration. This paper focuses on a concept where tar is removed at high temperature with an abundantly available catalyst: char. Char has been proven to be a perfect catalyst for the destruction of tars by both ECN and others [3]. The patented concept is called TREC: Tar REduction with Char. The TREC-module is to be placed directly downstream a gasifier, without intermediate gas cooling or other treatment.

## 2 TREC

### 2.1 The concept

Char has demonstrated to be an effective catalyst for the reduction of tar (the catalytic activity of char is attributed to the presence of inorganic compounds within the carbon matrix). Although e.g. air-blown fluidised bed gasifiers produce a gas that contain both tar (typically 10 $g/m_n^3$) and char (typically 10 $g/m_n^3$), catalytic tar reduction by char hardly occurs in practice because of the short residence time combined with relatively low temperatures. Also the tar-char contact generally is very poor. The TREC-concept aims at providing good contact with sufficient residence time at high temperature.

The design of the TREC-module is based on granular bed filtration technology. The char is trapped in a fixed bed and the gas (including the tar molecules) flows through the bed radially. The granular bed is constantly moving to avoid high pressure drops. Furthermore, the char particles are partly settled on top of the moving bed to get a more evenly distributed char concentration in the granular bed. This effectively prevents a high pressure drop. It also creates a larger reaction zone for tar reduction. The TREC-module is shown schematically in Figure 1.

Although the TREC-concept originally

relies on char as the catalytic component for tar reduction, the use of other catalytically active granules is also possible. This might not even be restricted to catalytic tar reduction, it also may include materials that remove other components from the gas by e.g. absorption.

Since the TREC-module is designed to trap char particles, it serves as a high-temperature filter. This might be a valuable asset for many other applications.

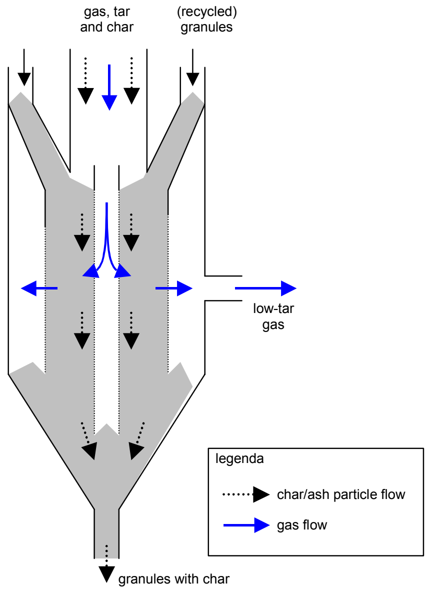


**Figure 1.** *Schematic representation of the cylindrically shaped TREC-module to remove tars, and particles downstream a biomass gasifier*

## 2.2 Lab-scale facility

The above-described TREC-module has recently been constructed on an 8 $m_n^3/h$ product gas flow scale at ECN. It is placed downstream an existing fluidised bed gasifier. Prior to the lab-scale design, a two-dimensional cold-flow facility was built and tested. Experiments revealed excellent filter efficiency of over 99%. Further evaluation of the experiments resulted in the parameters for scale-up to the cylindrically shaped lab-scale module.

# 3 EXPERIMENTAL RESULTS

Each experiment starts with a granular bed, which is free of carbon/char. Because a considerable fraction of the char entering the TREC-module is deposited on top of the moving bed, the char-rich zone slowly moves down the reactor. The tar reduction therefore is expected to increase with time, until the char-rich zone front reaches the bottom of the reactor. From then, the tar reduction remains unchanged. This is illustrated in Figure 2 where the calculated average char concentration in the reactor (not corrected for char gasification) is plotted against time. Also plotted is the pressure drop over the reactor and the tar dew point of the tars downstream the reactor.

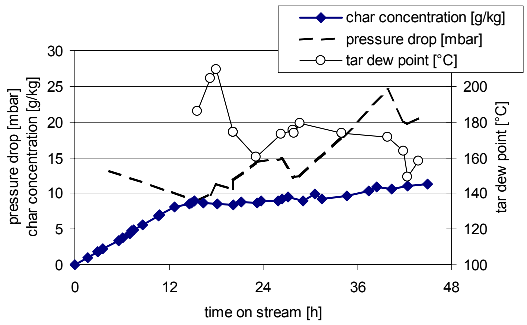


**Figure 2.** *Char concentration in the TREC-module and measured pressure drop and tar dew point of the cleaned gas*

Table 1 shows the average concentrations of the most important gas components before and after the TREC-module during several tests. The air-blown fluidised bed gasifier was operated with approximately 3.7 kg/h of dried beech wood at 850°C. The TREC-module was operated with silica sand at approximately 900°C. In order to overcome the temperature difference between gasifier and TREC-module (including energy loss of the connecting piping), 0.6 $m_n^3/h$ air is added in the central channel of the TREC-module. Additionally, 0.3 $m_n^3/h$ nitrogen is added to purge the sand flow. This results in an increased volume flow of approximately 15%.

From Table 1 it can be concluded that tar clearly has been reduced. Also $C_{2-5}$ hydrocarbons (mainly ethylene) turn out to be reduced significantly. Methane and $C_{6-7}$

(mainly benzene) on the other hand are hardly touched. Another observation is that the water-gas-shift reaction, which originally is far from equilibrium, moves towards complete equilibrium at an approximate temperature of 900°C in the TREC-module. This is the reason for the increasing $H_2$-concentration and decreasing $H_2O$ concentration. The char is assumed to be the main catalyst for the water-gas-shift reaction.

**Table 1.** *Typical product gas composition before and after TREC-module*

| | | before TREC | after TREC |
|---|---|---|---|
| CO | vol% wet | 14 | 14 |
| $H_2$ | vol% wet | 5.6 | 10 |
| $CO_2$ | vol% wet | 13 | 13 |
| $CH_4$ | vol% wet | 4.2 | 3.5 |
| $C_{2-5}$ | vol% wet | 1.3 | 0.6 |
| $C_{6-7}$ | vol% wet | 0.4 | 0.3 |
| $H_2O$ | vol% wet | 18 | 12 |
| tar ($C_{8+}$) | $g/m_n^3$ wet | 10.6 | 2.4 |

The amount of tar clearly decreases significantly as shown above. If specific tar classes are considered, it appears that heterocyclic tar (e.g. phenol) is almost completely reduced. The tar dew point that is calculated from the measured tar compounds is approximately 170°C downstream of the TREC-module. This is a significant improvement compared to the original dew point of 350°C in the raw product gas leaving the gasifier.

The tar dew point of 170°C is induced by a small fraction of unconverted heavy tar compounds ($C_{16+}$). Although these compounds are reduced significantly (over 90%) within the TREC-module, the influence on the tar dew point remains high. More information on tar dew points can be found in [4,5].

The filter efficiency turns out to be rather good. From the original 7 $g/m_n^3$ particles in the dry gas, less than 0.1 $g/m_n^3$ is left (99% filter efficiency) downstream of the TREC-module. Most of this can be attributed to the fine fraction present in the granular material applied during the test.

Recently, the TREC-module has been connected to the 8 $m_n^3/h$ indirectly heated (allothermal) gasifier at ECN [6]. This facility produces a $N_2$-free product gas with high amounts of hydrocarbons and 30 $g/m_n^3$ of tar in the wet gas. It has been shown that similar tar reduction efficiencies can be reached.

## 4 FURTHER RESEARCH

The TREC-module has shown to be capable of removing most of the tar from the product gas. Although this is a serious reduction and the tar dew point reduces to approximately 170°C, the remaining tar concentration is too high for most applications. Further research will be done to improve the tar reduction. The application of granular material with catalytic activity is an option. Also the use of fuels with more ash can improve tar reduction.

Another item of interest is the soot production. There are indications that a certain amount of soot formation takes place, which is undesirable from an efficiency point of view. This could also jeopardize smooth long-term operation.

## 5 CONCLUSIONS

The TREC-module is a practical way to reduce two problems of biomass gasification: “tar” and “char” causing fouling problems and efficiency loss respectively. The TREC-concept is based on granular bed filtration technology and it has proven to be a robust way to treat product gas from a gasifier. Several experiments were conducted with the TREC-module, with an accumulated operation time of over 100 hours. First results show a decrease of tar concentration of approximately 80%. The filter efficiency reached 99%. Pressure drops generally stay low and do not exceed 25 mbar. Further improvements are expected with the use of catalytic bed material. The latter will be tested in near future.

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## 7 ACKNOWLEDGEMENT

The authors like to acknowledge the European Commission for supporting the activities reported here. Most of the activities have been performed within the project Green Fuel Cell, which is part of the Sixth Framework Programme.