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# Tar removal from biomass product gas; development and optimisation of the OLGA tar removal technology

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# T TAR REMOVAL FROM BIOMASS PRODUCT GAS; DEVELOPMENT AND OPTIMISATION OF THE OLGA TAR REMOVAL TECHNOLOGY

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ABSTRACT: The main technical challenge in the implementation of integrated biomass gasification plants is the removal of tar from the product gas. ECN has developed the OLGA tar removal technology, based on gas scrubbing with oil. The OLGA tar removal technology has many advantages compared to alternative conventional tar removal approaches, *e.g.* no fouling, no water pollution, very low tar dewpoints. Tar dewpoints below -15°C can be achieved, allowing application of the gas for advanced catalytic applications. Extensive testing has been performed with the lab-scale OLGA unit at ECN. Very stable operation has been demonstrated for several hundred hours. In the pilot development the process has been modified to improve operational stability, *i.e.* mainly related to the oil circuits. In the experimental pilot programme the *"proof-of-concept"* for the OLGA process was delivered. The economy of the OLGA technology is very favourable at scales above approximately 4,000 $m_n^3$/h (*i.e.* corresponding to ~10 MW biomass input). The total specific costs are in the order of 1.5 €ct/$kWh_e$. Considering the elimination of the tar problem with OLGA, and the positive contribution to the reliability of the process, the economical perspective for OLGA is promising.
Keywords: Gas cleaning, gasification, combined heat and power (CHP), tar removal.

## 1 INTRODUCTION

Gasification (of coal) is an old technology that today is the key chemical process in almost every major method of energy generation, used in the production of electricity, in refineries, and in a variety of other commercial uses. The statement about the position of coal gasification, however, does not apply for biomass gasification. The main technical challenge in the implementation of integrated biomass gasification plants has been, and still is, the removal of tar from the product gas. "Tar" is equivalent to a major economic penalty in biomass gasification. Tar aerosols and deposits lead to more frequent maintenance and resultantly decrease of revenues, or alternatively, to higher investments. Furthermore, removal of tar components from the process wastewater requires considerable investments. Several measures for tar removal have been studied or are under investigation.

## 2 OLGA TAR REMOVAL TECHNOLOGY

Early 2001 the development of the "OLGA" was initiated at ECN. The OLGA is based on applying an organic scrubbing liquid (*i.e.* "OLGA" is the Dutch acronym for oil-based gas washer). In the development of the OLGA tar removal technology, ECN has chosen an approach that concentrates on the behaviour (*i.e.* the properties) of the tar and does not concentrate on the tar content. Hence, a "tar-free" product gas is synonymous to a gas "free of tar related problems". The advantages of the OLGA tar removal technology, compared to alternative conventional tar removal approaches, can be summarised as [1]:

- Tar dewpoint of clean product gas is below temperature of application, therefore there is no condensation of tars in system;

- No fouling of the system resulting in increased system reliability and higher availability;
- Tars are removed prior to water condensation to prevent pollution of process water;
- Tars can be recycled to gasifier and destructed avoiding the handling of problematic (and expensive) tar waste streams;
- Technology is scalable allowing the application from lab to commercial scales.

### 2.1 Process description

This paper summarises the status of the OLGA technology up to mid 2005. In Figure 1 a simplified process flow diagram for the OLGA is shown. It is assumed that the OLGA is operated downstream a high-efficient solids removal step (*e.g.* a hot gas filter). The OLGA gas inlet temperature has to be kept higher than the tar dewpoint, similarly the gas outlet temperature must be higher than the water dewpoint. In the OLGA the product gas is cooled, upon which the liquid tars are collected. Additionally, gaseous tars are absorbed in the scrubbing liquid at the resulting temperature. In the design of the OLGA the liquid tar collection and the gaseous tar absorption are performed in two separate scrubbing columns, *i.e.* the Collector and the Absorber. Although, both processes could be performed in a single scrubber unit, separation in two sections is preferred because of process operation considerations.

The liquid tars are separated from the scrubbing liquid and returned to the gasifier; also a small amount of the scrubbing liquid is bleed and recycled to the gasifier. For the absorption step, scrubbing columns were selected that are interacting with each other in a classical absorption-regeneration mode. The scrubbing liquid from the Absorber with the dissolved tars is regenerated in the Stripper. In case of air-blown gasification, air is used to strip the tar. Subsequently, the air with the stripped tars is used as gasifying medium. The loss of scrubbing liquid in the Stripper by volatilisation is minimised.

The cleaned product gas leaving the Absorber is “tar-free” (*i.e.* free of tar related problems) and can be treated further in the water-based gas cleaning, fired in a gas engine, or used for more advanced catalytic applications.

## 3 STATUS OF THE TECHNOLOGY

### 3.1 Lab-scale “Proof-of-Principle”

In the last three years an extensive research programme has been carried out in the lab-scale OLGA unit (*i.e.* 2 $m_n^3$/h of product gas). Experiments have proven that the OLGA process is capable of removing tars to very low levels, *i.e.* tar dewpoints below -15°C (for relevance of the tar dewpoint see reference [1]). Product gases made tar-free with the OLGA process are suitable for application in gas engines and even more demanding applications in Fischer-Tropsch and synthetic natural gas (SNG) synthesis processes [3].

In the ongoing R&D is aimed at continuous optimisation of the OLGA process, either by improving the performance and/or by decreasing the capital and operational costs.
In the experiments it was demonstrated that selecting alternative scrubbing liquids for the OLGA holds the opportunity to increase the removal efficiency of the hetero-cyclic (class 2) and light 2-3 ring aromatic (class 4) tar compounds in the OLGA Absorber. In this way the economics of the process can be improved either by decreasing the size of the Absorber (lower investment costs) or using a cheaper scrubbing liquid (lower operational costs) [1]. Furthermore, the tar-oil separation in the Collector was improved, allowing simplification and a more robust oil circuit, as well as lower operational costs.

OLGA is designed to operate in essentially dust-free gas. The tar removal performance of OLGA is demonstrated downstream a hot gas filter. Application of the OLGA process for combined tar and dust removal would make an upstream hot gas filter superfluous, which would have a drastic impact on the investment costs.

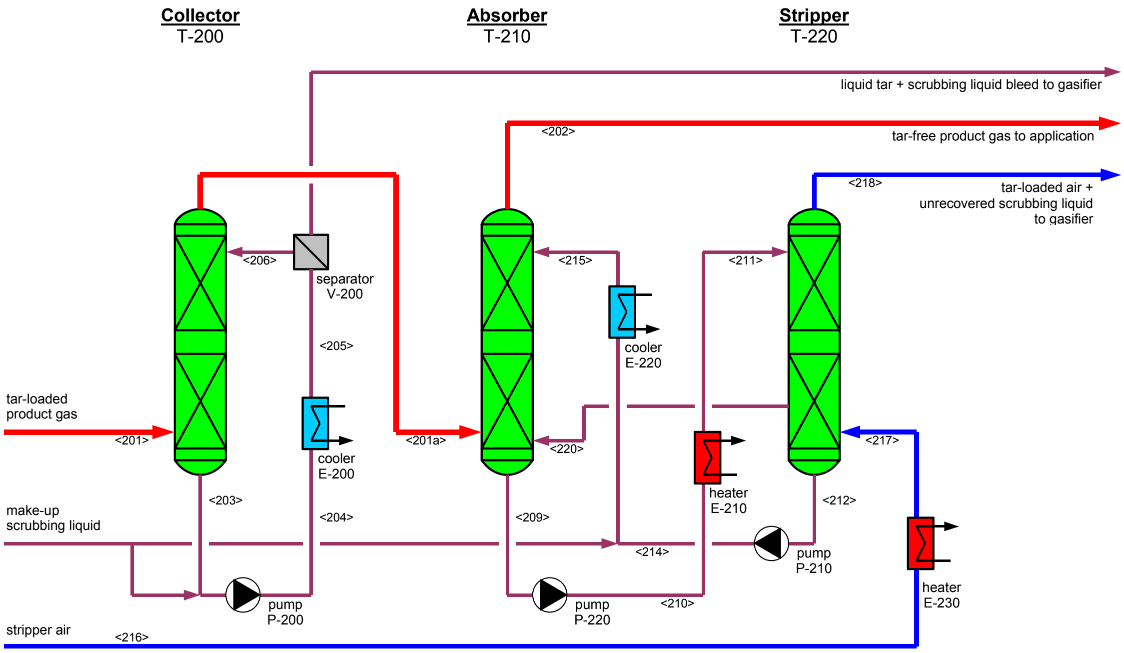


**Figure 1:** *OLGA process flow diagram*

Preliminary experimental results of short test in the lab-scale OLGA indicate that dust can be effectively (*i.e.* for 99.5%) removed in the OLGA without fouling of the OLGA column packing [1]. Tar removal performance, however, was negatively affected and the product gas after OLGA was not on specification. In ongoing R&D the combined tar and dust removal is further investigated aimed at defining a system line-up that is more cost-effective than the combination with a hot gas filter.

In total more than 1000 hours of experiments have been accumulated in the lab-scale OLGA unit. The unit is automated to allow un-attended and overnight operation; a single test run of mover 300 hours has been performed without OLGA-related unplanned stops.

## 3.2 Pilot scale "Proof-of-Concept"

The purpose of the pilot OLGA unit and the experimental programme is to deliver the *"proof-of-concept"* for the OLGA process and to identify critical issues in up scaling, equipment selection, and process design. The pilot OLGA unit is a hundred times scale-up of the lab-scale unit, *i.e.* 200 $m_n^3$/h of product gas. The pilot unit was designed by ECN based on the experience gained in the lab-scale unit. Dahlman carried out engineering and construction. For the pilot unit equipment was selected in such a way that unit would be a 'blueprint' for future commercial plants.

From 2003 through 2005 several test runs were performed with the pilot OLGA. During these operational tests most problems encountered were related to the operational stability and heavy tar removal performance of the Collector. The stability problems related to the oil Pump P-200 and the process interaction of the Pump with the oil Cooler E-200 (see Figure 1). These problems were not encountered in the extensive lab-scale test programme, as in the lab-scale set-up other hardware was applied and other operational approaches were followed (*e.g.* use of trace heating).

First tar removal results in the pilot OLGA have delivered the "proof-of-concept", *i.e.* that the process is in principle suitable for cleaning of product gas from biomass gasification and deliver a 'tar-free' gas (downstream a hot gas filter). However, the performance of the installations needed further optimisation to allow stable operation over prolonged periods. This especially comprised the operation of the oil circuit. Subsequently, the pilot unit was modified to have more operational flexibility in the oil cooling and circulation in especially the Collector oil circuit. The effectiveness of the modifications was proven in a second series test runs.

Current pilot experimental programme is directed towards investigating the combined dust and tar removal (*cf.* discussion on lab-scale unit).

## 4 ECONOMIC ASSESSMENT

The success of the OLGA application as part of integrated biomass gasification systems is determined by its technical performance but also, and maybe even more, by the economical perspectives. Compared to alternative conventional tar removal systems, the specific investment costs for relatively small OLGA unit are relatively high. However, the scale-up factor of OLGA (*i.e.* economy of scale) is relatively low, as the OLGA is based on easily scalable technology and does not become more complex upon scaling-up (Figure 2). At sizes above approx. 4,000 $m_n^3$/h (*i.e.* corresponding to ~10 MW biomass input), the specific investment costs stabilise around 200 €/$m_n^3$/h and the operational cost for utilities and scrubbing liquid consumption become determining [1].

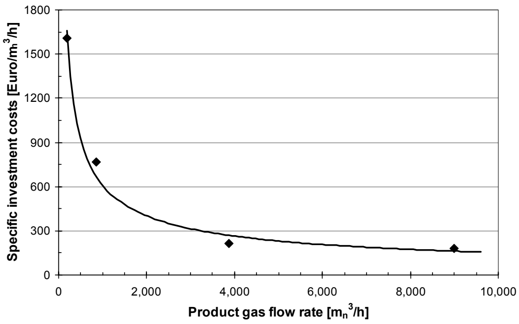


**Figure 2:** *Specific investment costs of OLGA as function of the size, determined by the gas flow rate*

In relation to the penalty to be paid for the tar problem (*i.e.* losses in revenues due to standstills and costs for water and tar-waste treatment), the total specific costs for OLGA are very promising. The total specific costs (*i.e.* the sum of the capital and operational costs expressed per $kWh_e$) are substantially lower than the quantified costs for the tar problem; see Table I. The costs can even be reduced with simple process optimisations. Considering the low total specific costs of OLGA, the elimination of the tar problem with OLGA, and the positive contribution to the reliability of the process, the economical perspective for OLGA is promising.

The data in Table I are determined for an OLGA downstream an air-blown circulating fluidised bed (CFB) gasifier. For the application of OLGA downstream an indirect or allothermal gasifier [2], the specific costs will decrease significantly, as the gas volume to be cleaned is smaller. The total specific costs for an OLGA in this application will be approximately 28% lower.

**Table I:** *Scale dependent specific investment and operational costs*

| **Scale** | | **Costs [€ct/$kWh_e$]** | | |
|---|---|---|---|---|
| $MW_{th}$ biomass | $m_n^3$/h wet gas | Specific invest. | Operational[a] | Total specific |
| 0.5 | 190 | 5.3 | 0.67 | 6.0 |
| 2 | 760 | 2.8 | 0.67 | 3.5 |
| 10 | 3800 | 0.73 | 0.67 | 1.4 |
| 25 | 9000 | 0.63 | 0.67 | 1.3 |

[a]. Operational costs = 0.07 €ct/$kWh_e$, (utility) plus 0.6 €ct/$kWh_e$ (scrubbing liquid consumption).

## 5 CONTINUATION

Although the OLGA development originates from biomass gasification research, the application of OLGA is not limited to removal of tars from biomass gasification product gases. The technology is scalable and suitable for pressurised operation. Therefore, the OLGA is applicable for removal of organic components or organic impurities (to very low levels) from all types of gases as well as for product recovery processes, *e.g.* coal gasification, cokes oven gas, process gases in chemical industry, natural gas upgrading, recovery of vaporised process oils, etc.

After the conclusion of the proof-of-concept phase, the generated information for optimisation of the design and hardware selection for future OLGA units, must be implemented. This will be done in the first demonstration and semi-commercial systems. An artist impression of a OLGA demonstration unit is shown in Figure 3.

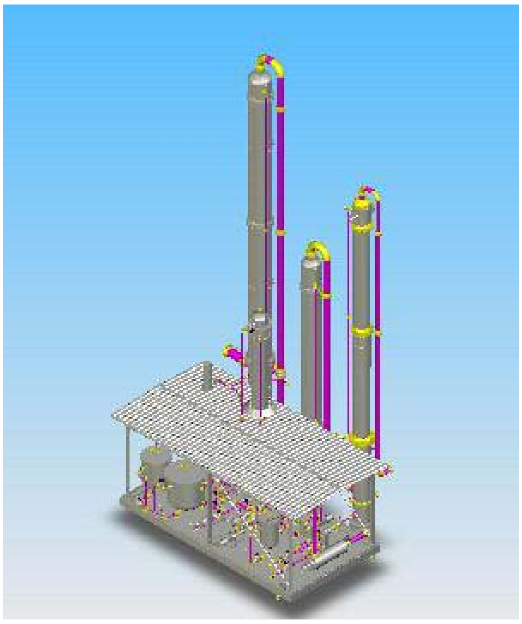

**Figure 3:** *Artist impression of OLGA demonstration unit*

It should be taken into consideration, however, that the operational and long duration experience with the technology is still limited. Therefore, sufficient additional time and budget should be reserved for commissioning and start-up of the next systems. In parallel, research is ongoing to further optimise the OLGA technology and demonstrate its performance during prolonged operation.

## 6 CONCLUSIONS

The OLGA tar removal technology has many advantages compared to alternative conventional tar removal approaches, *e.g.* no fouling, no water pollution, very low tar dewpoints. Tar dewpoints below -15°C can be achieved allowing application of the gas for advanced catalytic applications.

Extensive testing has been performed with the lab-scale OLGA unit at ECN. Very stable operation has been demonstrated for several hundred hours. In the pilot development the process has been modified to improve operational stability, *i.e.* mainly related to the oil circuits. In the experimental pilot programme the *"proof-of-concept"* for the OLGA process delivered.

The economy of the OLGA technology is very favourable at scales above approx. 4,000 $m_n^3$/h (*i.e.* corresponding to ~10 MW biomass input). The total specific costs are in the order of 1.5 €ct/$kWh_e$. Considering the elimination of the tar problem with OLGA, and the positive contribution to the reliability of the process, the economical perspective for OLGA is promising.

Dahlman Industrial Group is partner of ECN in the development and commercialisation of the OLGA technology. Commercial information on OLGA projects can be obtained from Dahlman.

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