Hydro Thermal Liquefaction (HTL) pilot plant for the production of bio-oil from lignocellulosic biomass

HTL design and operating main data
Built with the contribution of the EC for the BIOGO for Production Project – R&D FP7 program

Pressure		
Nominal	250	bar
Maximum allowable working	255	bar
Design	300	bar

Temperature		
Nominal	350	°C
Maximum allowable working	360	°C
Design	400	°C

Capacity	**15 kgh/h** (with 10% of biomass)
Bio-oil production	**0.45 kg/h**

March 2021

Design and Test of a Hydro Thermal Liquefaction (HTL) pilot plant for the production of bio-oil from lignocellulosic biomass.

Bio-oil is a kind of liquid fuel made from biomass materials such as agricultural crops, algal biomass, municipal wastes, and agricultural and forestry by-products via thermochemical processes. The interest in the production of bio-oil from biomass has grown rapidly in recent years, due to the possibility of producing fuels and chemicals from renewable resources. Bio-oil is the primary product of two main technologies: pyrolysis and Hydro Thermal Liquefaction (HTL); Elliott and Schiefelbein compared the elemental composition, water content, and heating values of bio-oil samples produced from pyrolysis and hydrothermal liquefaction; their results are shown in Tab.1.

Hydro Thermal Liquefaction typically produces higher quality oils than pyrolysis and the whole process possesses higher energetic efficiency (by avoiding the drying step); however, the pyrolysis process has the advantage of short residence times and lower capital costs. For comparison with HTL bio-oils, oils from pyrolysis typically have much higher oxygen and moisture content and contain a larger (75–80 wt%) proportion of polar organic compounds. One of the primary advantage of bio-oil produced through Hydro Thermal Liquefaction is the removal of oxygen heteroatoms; this oxygen is preferentially removed as CO_2 or H_2O: removing the oxygen as CO_2 may be desirable because has the advantage of increasing the H:C ratio, which can lead to a more desirable product.

Hydrothermal processes are based on the maintenance of biomass into a liquid phase media (water) at high temperature (350°C), to do so the slurry (water and biomass) pressure must be higher than the saturation pressure at the corresponding reaction temperature (250bar). In this condition water acts like a reactant and a solvent, extracting organic compounds from biomass and promoting bio-oil formation.

By varying the slurry residence time in the reactor and the reaction temperature it is possible to operate three Hydro Thermal processes: at low temperatures (180-250 °C) and long residence time (hours) the process is the Hydro Thermal Carbonization (**HTC**) and predominantly produces a char. At intermediate temperatures (200-370 °C) and short residence time (minutes) the process is the Hydro Thermal Liquefaction (**HTL**) and predominantly produces an oil. At high temperatures (>350 °C) and short residence time (minutes, highly depending on the catalyst adopted) the process is the Hydro Thermal Gasification (**HTG**), reactions occur that predominantly produce a gas phase.

One of the most interesting advantage of Hydro Thermal Processes is the absence of a specific required biomass moisture content and indeed very wet feedstock can be processed like damp wood, sewage sludge, manure and even microalgae. In fact most of the thermochemical conversion processes of biomass, such as pyrolysis and gasification, require the moisture content of the feedstock to be under certain limits (in general <15 wt%), because of the high energy requirements for water vaporization it makes drying to be one of the most energy consuming step of the whole process, affecting the overall economy.

Few pilot/demonstration HTL processes exist so far; the main known initiatives are the HTU® (hydrothermal upgrading) and the CatLiq® (Catalytic Liquefaction). The main difference between plant technologies is related to the feeding system that can assume both configurations: batch or continuous. Spike Renewables pilot plant is a continuous process designed focusing on costs reduction and to maximize yield and efficiency. The goal has been achieved by reducing critical components and designing an innovative and simpler process. Because of very harsh process conditions industrial applications undergo various challenges: process fluid is highly corrosive therefore all system components must be built by the utilization of expensive alloys; high operation pressure (250 bar) together with high temperature (350°C) requires specific components. Finally particular attention must be paid to gaskets and to the high pressure pump that must be capable to operate with slurry fluids (liquid with solid suspension).

In Figure 1 it is reported the Spike HTL process diagram with mass and energy balance, while in Figure 2 is possible to see a rendering of the plant with indications of main components.

The main design advantages of Spike HTL plant compared with existing solutions are the following:

- Continuous operation;
- No slurry recirculation loop after the reactor;
- Possibility to modify the residence time in the reactor using bypass 15', 30' or 45' to 1h;
- Bio-oil filtering section at high temperature;
- Containerized plant

Future improvement will regard the industrialization of the pilot plant, the possibility to increase capacity from actual 15kg/h, and the implementation of plant modifications to improve efficiency.

Figures and tables

	Hydro Thermal Liquefaction	Pyrolysis
Water content (wt%)	5	25
Heating content (MJ/kg)	35.7	22.6
Viscosity (cps)	15000 @ 61 °C	59 @ 41 °C
Elemental analysis (dry basis wt%)		
C	77	58
H	8	6
O	12	36

Tab. 1: Comparison of bio-oils properties from HTL and pyrolysis

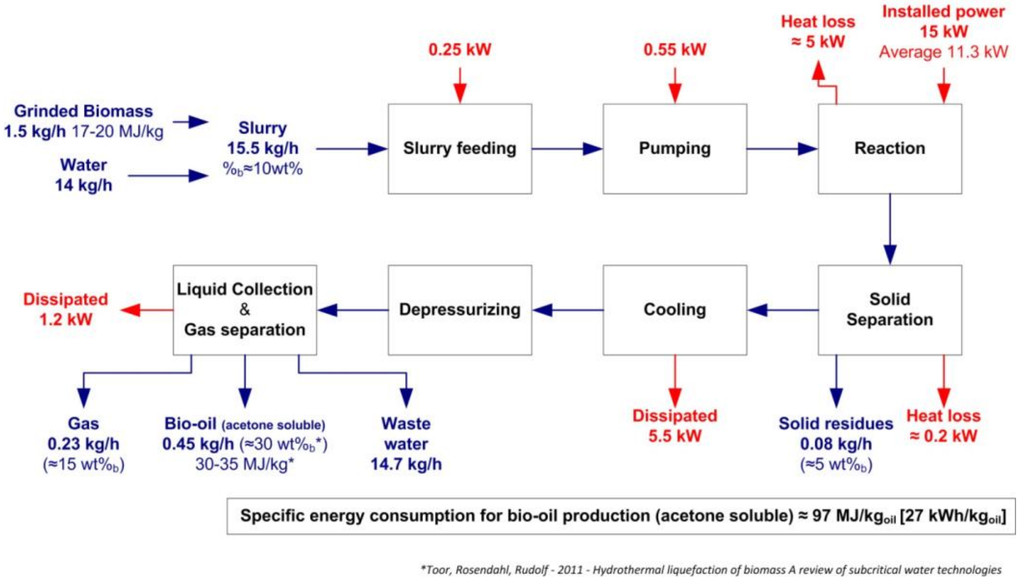

Figure 1: Mass and energy balance of the HTL process.

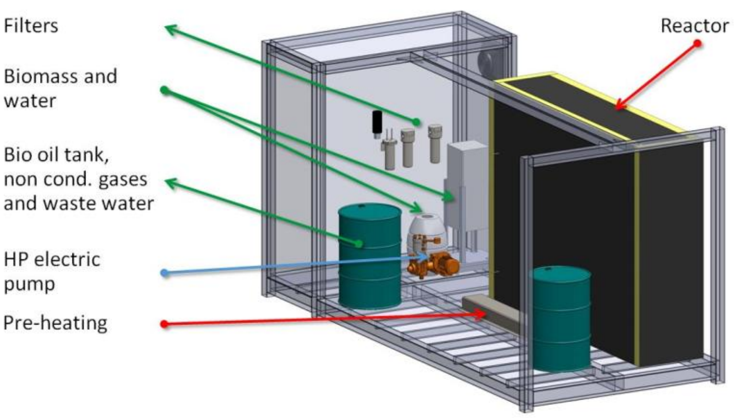

Figure 2: Rendering of the plant with shown of main components.

Spike Lab HTL plant: Slurry capacity (10%biomass) 15 kg/h Designed for lignocellulosic biomass and organic residues.

Patent
Pilot Plant for biomass Hydro Thermal Liquefaction (HTL) for bio oil production
PROPERTY: Spike Renewables Srl / RE-CORD
Patent application: n. FI2015A000127 date 29.04.2015 Patent n.1429628

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Hydro Thermal Liquefaction (HTL) can directly convert wet biomass and organic wastes into a liquid biocrude oil. The reaction takes place in a closed reactor at 200–350°C and 100–250bar. The conversion efficiency of biomass depends on various parameters including reaction temperature, retention time, composition of feedstock and adopted catalysts. Because of very harsh process conditions, industrial applications undergo various challenges: process fluid is highly corrosive therefore all system components must be built with expensive alloys; high operation pressure (250bar) together with high temperature (350°C) requires specific components.