Facilities

IFRF performs in-house experimental and modelling research designed to enhance its own data bank and develop the methodologies and protocols which are at the disposal of **IFRF Members**.
In addition, we

- Contract research for private organisations which require information about fuel and equipment characterization and in-flame measurement;
- Partner with industrial and research organisations in EU Funded projects;
- Develop, manufacture, sell and test measurement probes and systems;
- Facilitate access to research facilities and funding opportunities within a Europe and International wide network.

The facilities to which **IFRF** has access are available to us as a result of formal agreements with **Enel** and the **University of Pisa** and enable us to undertake experimental work on semi-industrial and pilot-scale furnaces and reactors. This brochure describes the **ENEL Livorno research facilities** and those of the **University of Pisa at S. Piero**.

To enquire about **contracting a research project** or for information related to the **manufacture or testing of measurement instruments** contact **Giovanni Coraggio** on *giovanni.coraggio@ifrf.net*

Favourable rates are offered to IFRF Members.

Within the EU funded **BRISK** project **IFRF** has also developed a database of research facilities across Europe.

Consult the database on our website at *http://www.efri.ifrf.net/organisations.html*

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FOSPER Furnace

FOSPER (FOrnace SPERimentale – Experimental Furnace) is a replica of the former IFRF Furnace #1 at IJmuiden. This rig can be used to do any kind of combustion test at semi-industrial scale. The numerous observation windows enable measurement of the profiles of the physical quantities inside the furnace and their behavior as a function of the combustion settings. This furnace has been used to characterize and develop new Low-NO_x burners and to test alternative fuels and new combustion technologies such as Oxy-combustion. In this case, a new cryogenic tank of oxygen and a new flue gas recirculation pipeline were added.

The furnace is constructed of 11 independently water-cooled refractory-lined sections. Along the side of the furnace there are 14 windows to insert measurement probes.

FOSPER rig during tests

Characteristics:

Max thermal load: 5 MW_{th}

Internal square cross-section: 2 x 2 m

Length: 6.38 m

Residence time: 2.55 s at the nominal load

Fuels: Solid fuels (coal, secondary fuels), oil and gas

Available measurements:

The chemical composition and the temperature of the flue gases are constantly monitored as well as all the flows and the temperature of input airs and fuel. Through the observation windows it is possible to take measurements inside the furnace with IFRF probes. These include chemical composition and temperature profiles, radiation measurements, gas velocity field, fly ash iso-kinetic sampling, and total heat flux measurements.

IPFR

The **IPFR** (Isothermal Plug Flow Reactor) is an entrained plug flow reactor under isothermal conditions and can provide detailed information about the combustion process. The reactor can be used to represent conditions found in full scale applications. Heating rates of the order 10^4-10^5 K/s are easily obtained as well as typical gas temperatures and composition.

The IPFR is constructed in three main sections. **A Gas preheating section** contains the precombusting chamber fired by a 60 kW_{th} aerodynamically air-staged natural gas burner. The precombustor provides hot flue gases in the range of 950° - 1500° C which ensure high heating rates at the entrance of the reactor. The other two sections are the **Reactor tube** which consists of eight independently controlled modules and a **Collection system**.

IPFR rig ready for tests

Characteristics:

Reactor length: 4.5 m

Reactor inner diameter: 150 mm

Maximum thermal input for natural gas: 60 kW_{th}

Operating temperature: 700 – 1400 °C

Particles residence time: 10 – 1500 ms

Available measurements:

Chemical composition of the flue gas

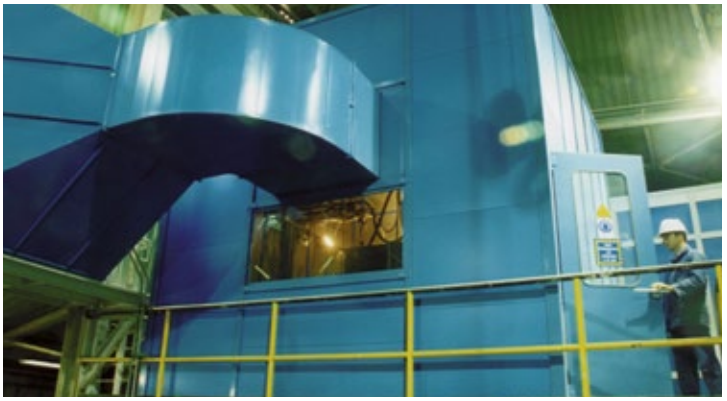
Temperature of the flue gases measured with the IFRF pyrometer

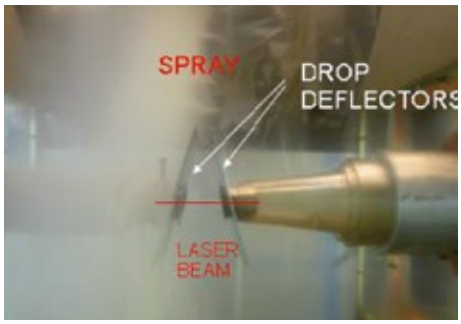
The unit also can be used for tests in various combustion conditions such as oxy-fuel combustion or gasification without oxygen.

The temperatures of each of the eight modules and of the pre-combustor are measured with thermocouples.

ISA – Spray Test Rig

The **ISA** rig (Impianto Sperimentale Atomizzatore - Experimental Atomizer Rig) has been developed for the study and characterization of full scale oil burner atomizers for energy plants or industrial furnaces. The flexibility of this rig enables the study of several kinds of atomizers e.g. return-flow and steam-assist. With this equipment it is possible to measure the size distribution of the drops produced by the atomizer.
In place of the fuel oil, simulation oil is utilized at ambient temperature. The latter has the same physical characteristics as fuel oil at 120° C - normal operating conditions with real burners. For safety and operational reasons, compressed air is used instead of steam for the steam-assist atomizers.





Spray Test rig ISA: Characterization of the bi-phase flow field on liquid fuel lance for power plants using Malvern apparatus

Characteristics:

Flowrate ranges: 100-10000 Kg/h for the simulation oil 90-1500 Kg/h for the atomization air

Max P_{oil}: 70 barg

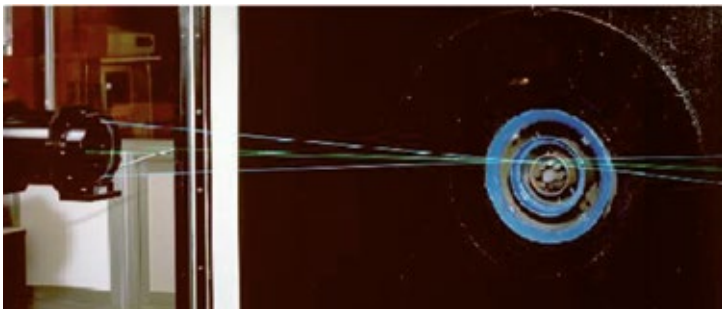
Max P_{air}: 10 barg

Available measurement equipment:

Malvern Particle Sizer
Light/Laser Sheet Visualization

Burner Aerodynamics Lab

The facility enables a deep characterization of the aerodynamic "cold" flow field generated by a burner or any combustion device. Tests are mainly carried out to understand air distribution and fuel mixing. The data produced with this analysis are a useful input for the validation of mathematical models.



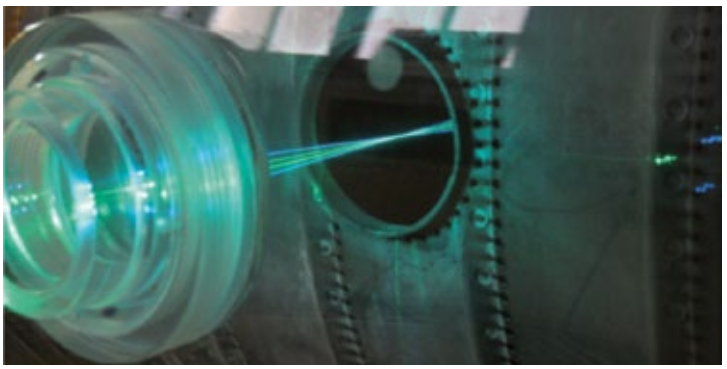
Burner Aerodynamic Lab: Flow field characterization on boiler burners and GT combustor using laser and hot wire techniques

Characteristics:

Different fans are available and their use depends on the conditions which need to be reproduced in the tests. The air flow rate can vary between 490 and 20000 m^3/h with a head pressure varying between 70 and 1170 mmH_2O.

Available measurement equipment:

5-Hole Pitot tube
Laser Doppler Velocimetry (LDV)
Laser Sheet Visualisation (LSV)
Hot Wire Anemometry (HWA)
Phase Doppler Particle Analyzer (PDPA)



SCR – Catalytic Test Rig

SCR (Selective Catalytic Reduction) test rig is used to study the efficiency of full scale DeNOx Monolith Catalysts (150 mm x 150 mm x 800 mm) used in the industrial SCR filter to reduce NO_X in exhaust gas produced by fossil fuel combustion. The conversion efficiency of NO_X into N_2 and H_2O and the undesired SO_3 formation rate from the oxidation of SO_2 can be valued as a function of the gas temperature, the gas velocity inside the monolith catalyst and the input molar ratio NH_3/NO_X.

Characteristics:

The exhaust gas flowrate can vary between 10 and 300 Nm^3/h with a range of temperature between 280° C and 320° C. The rig is fed with the real exhaust gas produced by the Power Plant Marzocco situated nearby the Experimental Area. As an alternative, it can be fed with the exhaust gas coming from the 500 kW_{th} test furnace when gases with different composition are needed. It is possible to add ash or other pollutants to the gases entering the filter in order to study critical work conditions.

SCR: Characterization of monolith catalysts for NOx reduction

CASPER – 6MW$_{th}$ Boiler

CASPER (CAldaia SPERimentale – Experimental Boiler) is projected to test and develop burners of semi-industrial scale. The burner can be fired with liquid and gas fuels and new burner development is facilitated by studying the effects of different settings on the emissions (NO_X, CO, particulate and TOC). The plant may also be used to verify atomizer efficiency or to characterize the effect of additives for combustion.

Characteristics:

Max. input power: 6 MW_{th}

D-shape boiler, inner dimensions: 1.65 m × 2.2 m × 4.5 m

Fuels: Gas and liquid fuels

Possible flue gas recirculation

Lateral measurement windows

Available measurements:

The windows on the side of the furnace allow the use of any probes to measure the profiles of physical parameters inside the boiler. Measurables include temperature, gas species composition, velocity field, radiation, and emissions' chemical composition, in particular ultrafine particles.

CASPER: 6 MW_{th} single burner test rig

TAO – Optical Test Rig for Gas Turbines

TAO (Turbogas con Accessi Ottici) is a test rig with quartz windows for the optical analysis of the flame in gas turbine development. In addition to its use in characterizing and developing burner prototypes for gas turbines, **TAO** enables the advanced analysis of flame radiation. **TAO** has also been used to study processes such as premixing and catalytic combustion, active systems to dampen combustion oscillations in gas turbines, and the development of non intrusive diagnostic instrumentation.

Characteristics:

Max Power: 400 kW_{th}

Internal diameter: 320 mm

Length: 850 mm

Max diameter of the burner prototypes: 120 mm

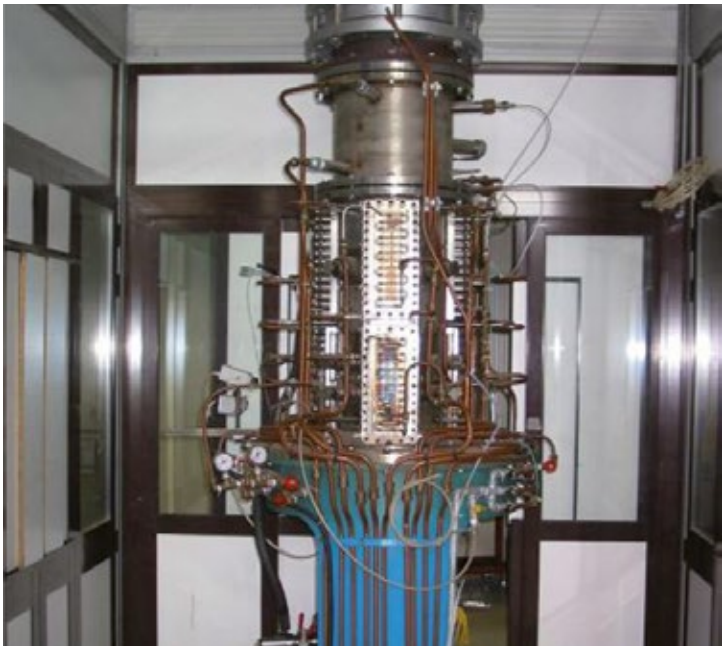
Fuels: Natural gas, hydrogen, (liquid fuels)

Walls with optical access (quartz windows)

Gas turbine Combustor: Scaled Fiat GT 50, Siemens V64.3A

Available measurement equipment:

LDV
High speed camera
UV photometer



TAO: Optical Test Rig for gas turbine burners and for development of GT view probe

500kW$_{th}$ – Test Furnace

This furnace is used to test low scale burners and study their emissions (NO_x, SO_2, CO, particulate, TOC) with different fuels and at different settings.
The rig is used also to study slagging and fouling mechanisms, to validate mathematical models and to perform co-combustion trials.

Characteristics:

Max input power: 500 kW_{th}

Dimensions: 1.6 m x 1.6 m x 5.00 m

Fuels: Solid fuels (coal, secondary fuels), oil and gas

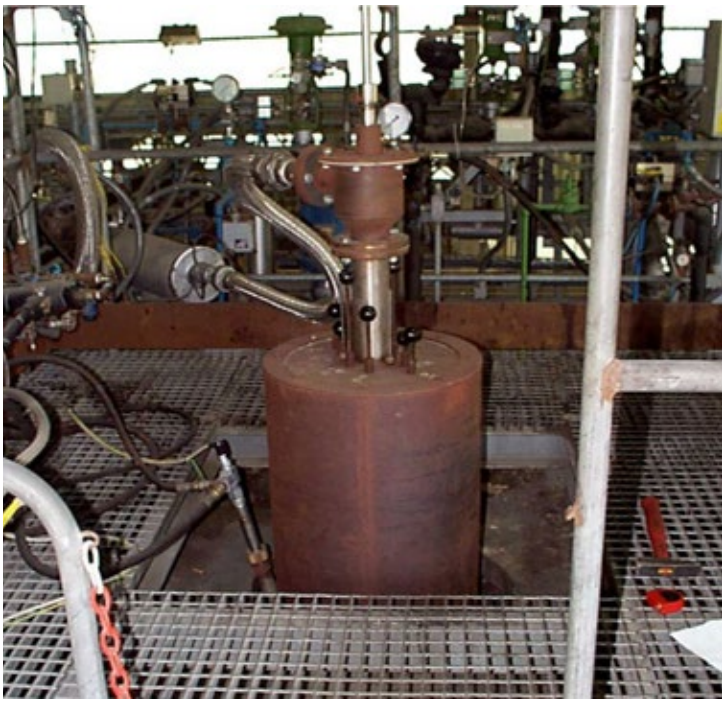
Refractory lined walls

Lateral measurement windows

Cooling pipes can be inserted inside the combustion chamber

The flue gases are cooled by two heat exchangers

Sampling ports in the flue gas train



500 kWth furnace

San Piero Bio-Energy Farm, University of Pisa

The area is composed of three integrated facilities (GASTONE/TAREK, VEGA, ETOS) which can operate singularly or together

IFRF CRIBE

IFRF has access to the Interuniversity Research Centre on Biomass for Energy at San Piero outside Pisa. The area is composed of three integrated facilities, **ETOS**, a bio-ethanol plant, **GASTONE/TAREK**, a downdraft fixed bed gasifier and tar cracking unit, and **VEGA**, a vegetable oil treatment and trans-esterification plant. The units may be operated singularly or together.
The plants are equipped with a large set of measures and in all cases experimental activity is supported by a dedicated characterization laboratory located in the Department of Industrial and Civil Engineering at the University of Pisa.

Bio-ethanol plant (ETOS)

A pilot scale facility developed to study the production of ethanol from lignocellulosic feedstock. Components include:

- pre-hydrolysis reactor to extract cellulose from the wood sawdust with steam and sulphuric acid;
- filter press to separate lignin from the pre-hydrolysis and solid residues from the fermentation bulk;
- 30 L jacketed fermentation tank equipped with cooling/heating jacket.
- distillation system (30 L tank equipped with a heating jacket, packed column and condenser.

The system is equipped with temperature, pH and pressure controls and a weight recording system.

Services offered:
The system is used primarily to test agricultural harvesting and processing residues as feedstock sources for bio-ethanol production. It also enables the testing of different pre-hydrolysis conditions and reactants, and the assessment of different enzymatic formulation for the fermentation reaction.

200kW$_{th}$ Downdraft fixed bed gasifier (GASTONE)

A pilot scale throated downdraft 200 kW$_{th}$ gasifier developed to gasify lignocellulosic biomass in air.

Nominal input: 40 kg/hr of biomass

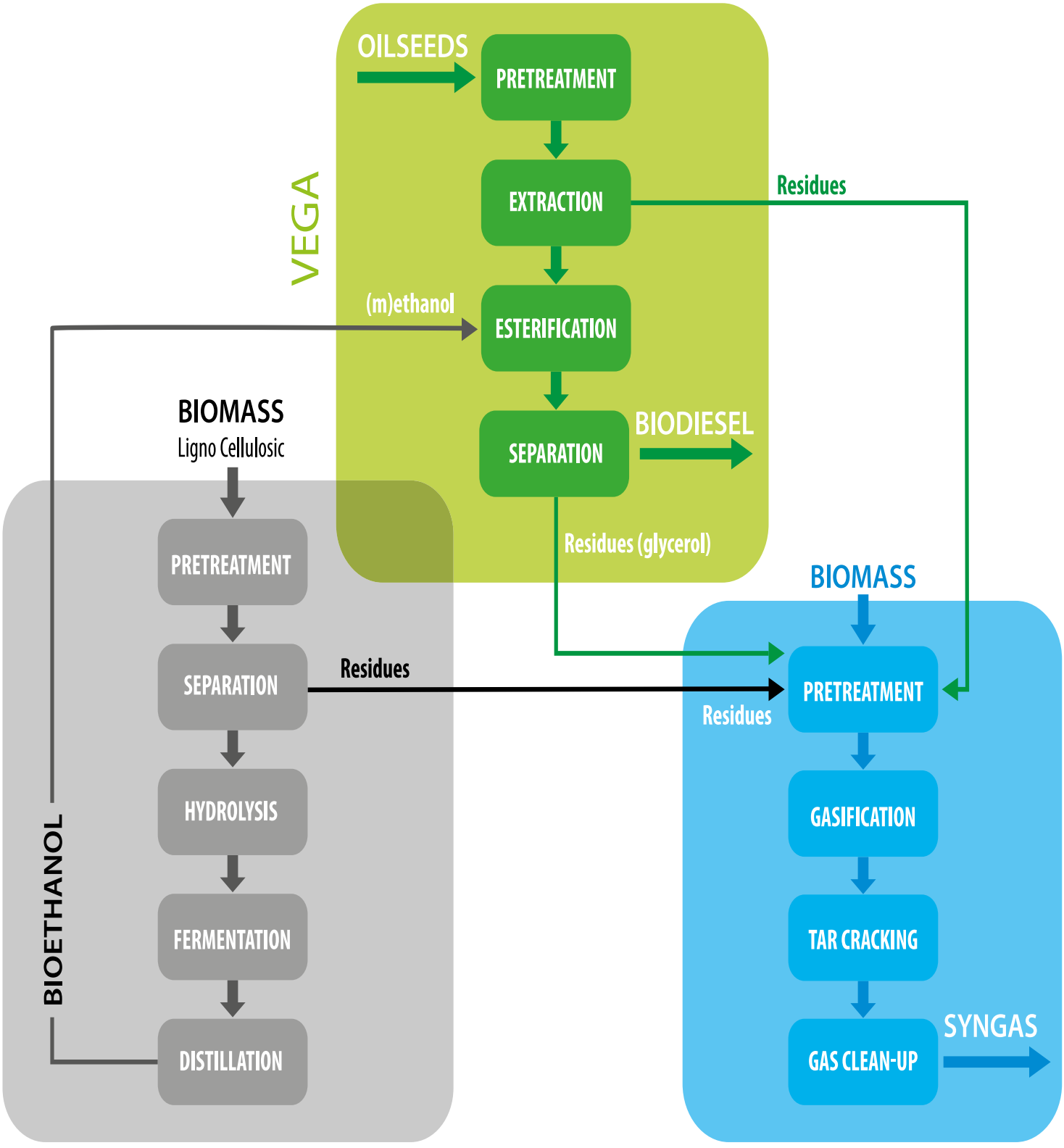
Maximum moisture content: 20%

The chipped biomass (0.8-6.3 cm nominal size) is charged to the gasifier via a screw conveyor controlled by a level sensor. A fun-blower at the end of the cleaning line causes the plant to operate slightly below atmospheric conditions. Air enters the gasifier through four nozzles positioned in the oxidation zone and the oxygen content may be enriched.

The biomass chips are supported on a grate at the bottom of the gasifier and become smaller as the gasification reactions proceed and the biomass residue (vegetal charcoal) falls under the grate. The charcoal is washed away to a settling tank and recovered with a screw conveyor. The gas produced (roughly 100 Nm^3/h) moves upward in an external ring and enters a clean-up system composed of a cyclone, a venturi scrubber, a chiller-condenser and two sawdust filters.

The plant is equipped with in-field measurements (pressure, level, temperature, flow rate) and sampling systems, such as a particles collector and tar sampling system. A gas sampling line has been developed to allow gas detection with FTIR and Micro-GC.

Services offered:
The facility is used to evaluate the suitability of different biomasses and wastes for the gasification process. Gas cleaning system performance is also tested, and particulate abatement efficiency and characterization study the effect of O_2 enriched air on the gasification process. The tests are integrated with laboratory activities focused on biomass characterization (TGA, CHN, calorimetry, CHL composition) and residues analysis (TGA, CHN, HPLC, SEM). Work can be coupled with modelling studies of the gasification process by means of process simulators.


OILSEEDS
PRETREATMENT
EXTRACTION
Residues
VEGA
(m)ethanol
ESTERIFICATION
BIOMASS
Ligno Cellulosic
SEPARATION
BIODIESEL
Residues (glycerol)
PRETREATMENT
BIOMASS
SEPARATION
Residues
Residues
PRETREATMENT
HYDROLYSIS
GASIFICATION
FERMENTATION
TAR CRACKING
BIOETHANOL
DISTILLATION
SYNGAS
GAS CLEAN-UP
ETOS
GASTONE / TAREK

Tar cracking reactor (TAREK)

A lab-scale derivation of the main gas clean-up system of the gasifier with a reactor diameter of DN65 and bed length 400 mm.
5 Nm^3/h of the gas from the cyclone enters the tar tracking line via a suction pump positioned at its end. A hot gas filter reduces the particulate content, a bauxite bed abates alkaline vapours, and tar cracking is effected by guard bed and main bed reactors. The gas exiting the line is destined to the flare. Whilst the guard bed may be loaded with mineral materials such as dolomite or olivine, the main bed is designed to support a metal catalyst. Both are positioned into cylindrical electric heaters to guarantee accurate temperature control.
TAREK is equipped with in-field measurements (flow rates, temperatures, pressure drops); tar sampling system and gas detection systems (FTIR and Micro-GC).

Services offered:

TAREK is used to evaluate the effectiveness of different materials in cracking tar in the gas stream produced under real gasification conditions. Controls in the two reactors enable measurement of temperature effects well as kinetic studies.

Vegetable oil treatment and trans-esterification plant (VEGA)

VEGA is a pilot scale facility developed to study the production and trans-esterification processes of vegetable oil. The plant includes an oil seeds squeezer (30 kg/h) and a filtration system. Its core is a 200 L batch reactor equipped with a hot water heating jacket, a loading cell system, methanol (or other alkyl donor) and catalyst dosing devices, and a settling tank. The reactor is specifically designed for trans-esterification conditions and can be continuously purged with nitrogen to remove the vapour phase methanol from the reactor. The system reproduces all the phases of the vegetable oil refining and biodiesel purification process, such as oil degumming, oil neutralization, methyl-ester separation from glycerol through settling and methyl-ester purification through methanol evaporation. The plant is equipped with temperature controls and a weight recording system.

Services offered:

VEGA is used to evaluate the effect of different operating parameters (temperature, catalyst, reactants) as well as the oil feedstock on trans-esterification reactions. It allows various experimental studies related to vegetable oil (degumming and neutralization conditions, free fatty acids removal) and biodiesel (low temperature oxidation or polymerization of glycerol, trans-esterification with ethanol).