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Biooil® Production at Dynamotive's Guelph Plant

Cellulose Based BioOil® Aimed at Industrial Fuels Market and Input to BTL Plants

Dynamotive Energy Systems announced it completed production runs of BioOil® in its new generation plant in Guelph, Ontario, Canada. Intermediate grade BioOil®, BioOil Plus™, which has higher calorific value than regular BioOil®, was produced. The runs the first of a number of test runs planned that are designed to take the plant to full production in accordance with the commissioning plan underway.

Figure 1. Dynamotive's Guelph Biofuel Plant overview.

Dynamotive and Tecna's engineers are reviewing operational data, and testing is being conducted on the fuel produced. Periodic updates are posted on Dynamotive's website.

Dynamotive plans to market this renewable fuel with the name 'BioOil Plus™' as a green and cost competitive alternative to heating oil, fuel oil, natural gas and propane in industry. Industrial fuels represent approximately 20% of hydrocarbon use worldwide.

Further, Dynamotive demonstrated in earlier tests that BioOil Plus™ can be used as an input to Biomass to Liquid Processes (BTL) as a cost effective means of delivering biomass energy to these plants and in doing so break down cost and logistic barriers to the production of mobile fuels from biomass. Specification on BioOil Plus™ and industrial application information for the fuel are available online.

"Cellulose-based fuels present the next frontier in sustainability and Dynamotive's pioneering position in advanced generation biofuels is further enhanced through the achievement of this new milestone. Dynamotive believes that BioOil presents a third alternative liquid fuel to coexist with ethanol and biodiesel," said Dynamotive's President and CEO Andrew Kingston. "By being able to exploit any cellulose raw materials, e.g. forest industry residues, bark, biomass from fields I believe we can become a great contributor to the energy mix and accelerate the adoption of cellulose based fuels."

Recently, at a renewable energy conference in Buenos Aires, Argentina, Kingston announced that the company reached an agreement in principle with the Provincial Government of Corrientes, in northeast Argentina, for Dynamotive, its affiliate, local and international partners to develop, subject to financing and other conditions, six similar plants in that country at a total estimated cost of US $120 million.

Dynamotive's other plant in West Lorne, Ontario, located midway between Toronto and Detroit, Michigan is now undergoing an upgrading of its systems; information on this plant operations and the status of the current upgrade can also be followed in the company's website *www.dynamotive.com*

Converting Agricultural Wastes into Valuable Green Fuels and Green Chemicals

By Franco Berruti and Cedric Briens, Department of Chemical and Biochemical Engineering, The University of Western Ontario, Canada.

Each year, millions of tonnes of agricultural matter are burned or tilled back into the earth; while some view this as a cost of farming, Canadian researchers at The University of Western Ontario *(http://www.eng.uwo.ca/research/fluidization/default.htm)* and Dorchester, Ontario-based Agri-Therm Limited *(http://www.agri-therm.com/)* see it as an opportunity.

Developed by Franco Berruti and Cedric Briens, both Chemical and Biochemical Engineering professors at Western, the first pilot of the 10 tons per day Mobile Fast Pyrolysis Machine produces valuable green bio-products and green renewable energy from agricultural materials such as sugar cane residues, tobacco, dry distiller grains, rice straw, flax straw and coffee husks. Ron Golden, President of Agri-Therm, explains that the mobile pyrolyzer represents an exciting breakthrough, creating products out of low-value or negative-value wastes right at their source. Agri-Therm is a spin-off derived from Berruti and Briens' research with help from the University's Industry Liaison office.

Using the process known as fast pyrolysis, which involves the decomposition of material by rapidly heating it in the absence of oxygen, the mobile pyrolyzer converts ground up solid waste material into bio-oil, which can be further refined and processed into fuels, pharmaceuticals, pesticides and food additives. Solid residues can also be used to produce valuable bio-char or as fertilizers or solid stabilizers. The mobile pyrolysis unit is supported by significant R&D work being conducted in the lab using a smaller and well instrumented 1 kg/h pilot plant, by sophisticated analytical facilities, and by a large team of graduate students.

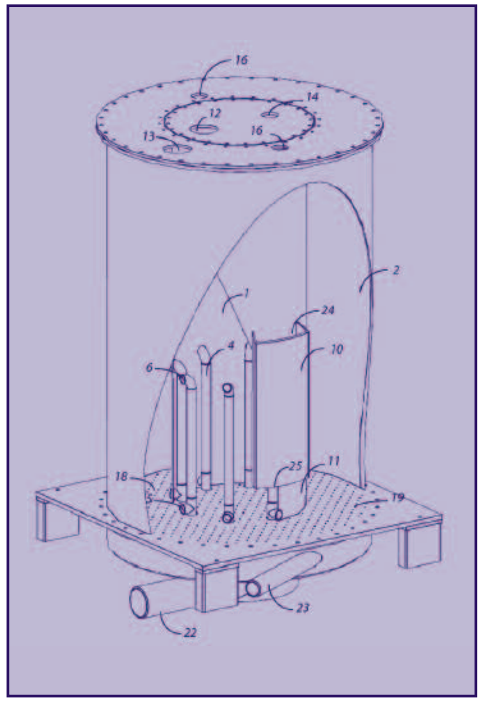

Figure 1: The pyrolysis reactor.

The optimal pyrolyzer needs to be compact, easy to operate, and able to process a wide variety of agricultural feedstocks. Ablation processes are mechanically complex and circulating bed processes are inflexible, not compact, and difficult to operate. It was, therefore, decided to use a bubbling bed pyrolyzer, suitably modified for flexibility, compactness, and ease of operation. The standard method of heating the reactor with heat exchanger tubes through which combustion gases are flowing is not compact because heat transfer between a gas and a tube wall is relatively poor. The mobile pyrolyzer will, therefore, use a different method. As shown in Figure 1, the pyrolysis reactor is an annular fluidized bed and the heat is generated by combustion of gas, solid or liquid by-products in a central, cylindrical fluidized bed.

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Figure 2: The mobile fast pyrolysis machine.

Figure 3: Cedric Briens and Franco Berruti.

Heat is transferred through the wall separating the two beds. Special lift tubes are used to increase the rate of heat transfer: solids from the reactor enter the lift tubes (item 5 on the diagram on page 3), are picked up by a stream of injected gas, gain heat as they rise through the tubes, which are immersed in the burner, and are released back to the pyrolyzer (item 6 on the diagram on page 3). Having a fluidized bed on both sides of the wall minimizes the required heat exchange area, since the heat transfer coefficient between a fluidized bed and a metal surface is very high.

A problem with standard bubbling beds is that light particles of agricultural biomass have a lower density than the bed and tend to float at its surface, which results in poor ablation and heat transfer, and, hence, poor product quality. An additional feature of the mobile pyrolyzer is that the stream of solids discharged by the lift tubes, above the surface of pyrolyzer bed, will drag down into the bed any biomass particle floating on the bed surface. The lift gas will also be introduced at the bottom of each lift tube with a nozzle specially designed to provide selective attrition of the char, so that it can be elutriated out of the reactor bed. Char cannot be allowed to accumulate in the bed, since it would degrade the fluidization quality and may act as a catalyst for undesirable cracking reactions. This design should allow for the use of larger biomass particles than regular bubbling beds, which would save on grinding costs.

The mobile pyrolysis unit can be moved onto a field or into a region, making it more cost-effective to use materials that have traditionally been unused. Agricultural wastes are typically seasonal and spread over large areas; consequently, stationary processing plants may not be economically viable. Agri-Therm's mobile technology offers an innovative solution for the efficient transformation of a wide variety of waste materials into valuable 'green' chemicals or carbon dioxide-neutral renewable energy.

Currently, Agri-Therm and the University are pursuing a partnership with tobacco farmers to extract nicotine for pharmaceutical purposes, including nicotine patches, and for insecticides. Additionally, the USA, Egypt, South Africa, Tanzania, India and Mexico have expressed interest in the technology as a means of reducing pollution, generating energy and helping farmers.

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BEST Pyrolysis Technology: A Solution for the Greenhouse Challenge

By Adriana Downie, BEST Energies, Australia.

BEST Energies was started in Australia in 1985 by innovative engineers who saw the need to provide technologies for the greenhouse challenge. Through years of experience, research and development work, BEST assessed a full range of renewable solutions and prioritised which technology would be best to achieve mitigation of climate change and yet provide the most attractive economic drivers. Their answer – slow pyrolysis.

Slow pyrolysis has distinct advantages over other technologies in that it combines solutions for biomass waste management and resources recovery, with the production of renewable 'green' energy, the increased sustainability of agricultural soils, and rural development. Each solution bringing its own income stream that contributes to the overall feasibility of the project.

As a renewable energy solution, this technology is remarkably flexible and is suitable for implementation in rural and remote communities. For example, agricultural wastes, instead of presenting an environmental risk, can be used as a resource and converted to energy in these areas where conventional energy sources are stretched and expensive. The syngas stream can be converted to electricity and/or thermal energy which can then be used either by industry or domestically.

The slow pyrolysis process is essentially the thermochemical decomposition of organic material (biomass) at elevated temperatures in the absence of oxygen. The feed material is dried and fed into a heated kiln. As the paddles in the kiln pass the material through, it reacts to produce an off-gas (syngas), which is continuously removed from the kiln and utilized for its energy value in much the same way as natural gas or LPG. Approximately 35% by weight of the dry feed material is converted to a high-carbon char material, which is a product in it own right as a soil amendment, fuel, or filtration media.

As proof of concept BEST Energies Australia has a fully operational 300 kg/hr demonstration plant. (See Figure 1). This unit includes fully integrated energy utilization, proprietary gas clean-up system and an operational internal combustion engine generator running on syngas produced from the pyrolysis kiln. A significant amount of experience and process data have been gained operating this unit on a range of feedstocks including; paper sludge, cow and poultry manures, rice hulls, green-waste and wood-waste. From this data the design has been scaled up into a 48 and 96 ton/day (dry feed basis) commercial modular units. These modular units can be designed with an engine component for electricity production or to interface with thermal energy processes such as steam boilers.

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Figure 1: The 300kg/hour slow pyrolysis demonstration plant.

Figure 2: The engine generator.

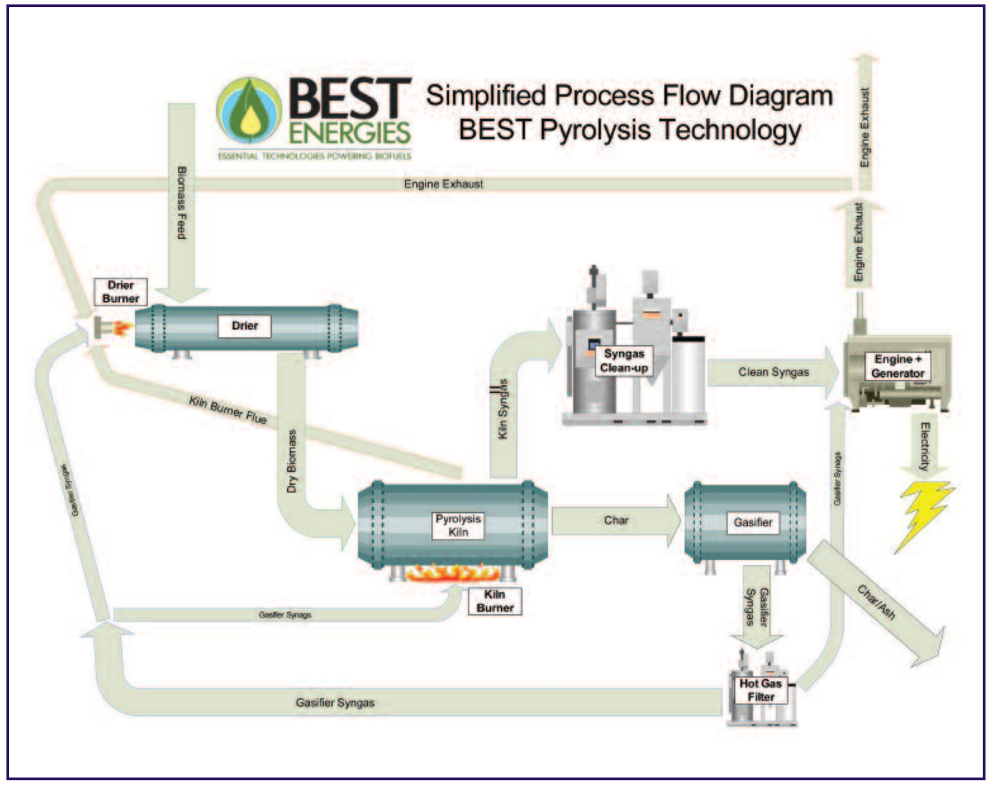

Figure 3: The BEST pyrolysis technology flow diagram.

BEST Energies has been actively developing the market for Agrichar in the agricultural sector. Char is claimed to increase agricultural productivity and fertilizer use efficiency by restoring organic carbon and enhancing the physical, chemical and biological soil properties. BEST has been working collaboratively with researchers from the New South Wales Department of Primary Industries (NSW DPI) to understand the agronomic benefits of chars manufactured from a range of biomass feedstocks and to conclusively (and scientifically) prove such claims. The results from initial pot trials were so successful, with some char amended treatments yielding 266% of the controls, that field trials have been initiated. This work has also confirmed findings from other international research groups which have reported improvement to soil health factors including: water holding capacity, soil pH, cation exchange capacity (CEC), tensile strength, nutrient cycling/retention and soil biology.

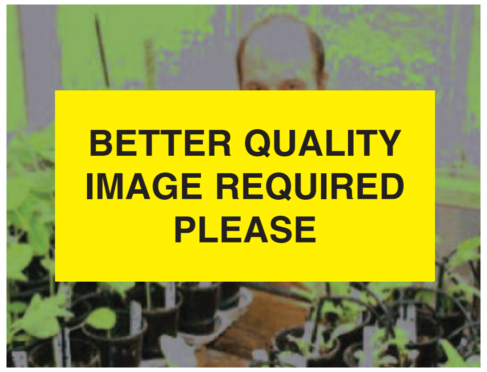

Figure 4a & b: Agricultural trials have been performed by the NSW Department of Primary Industries on the Agrichar Product Produced by the Commercial Pilot.

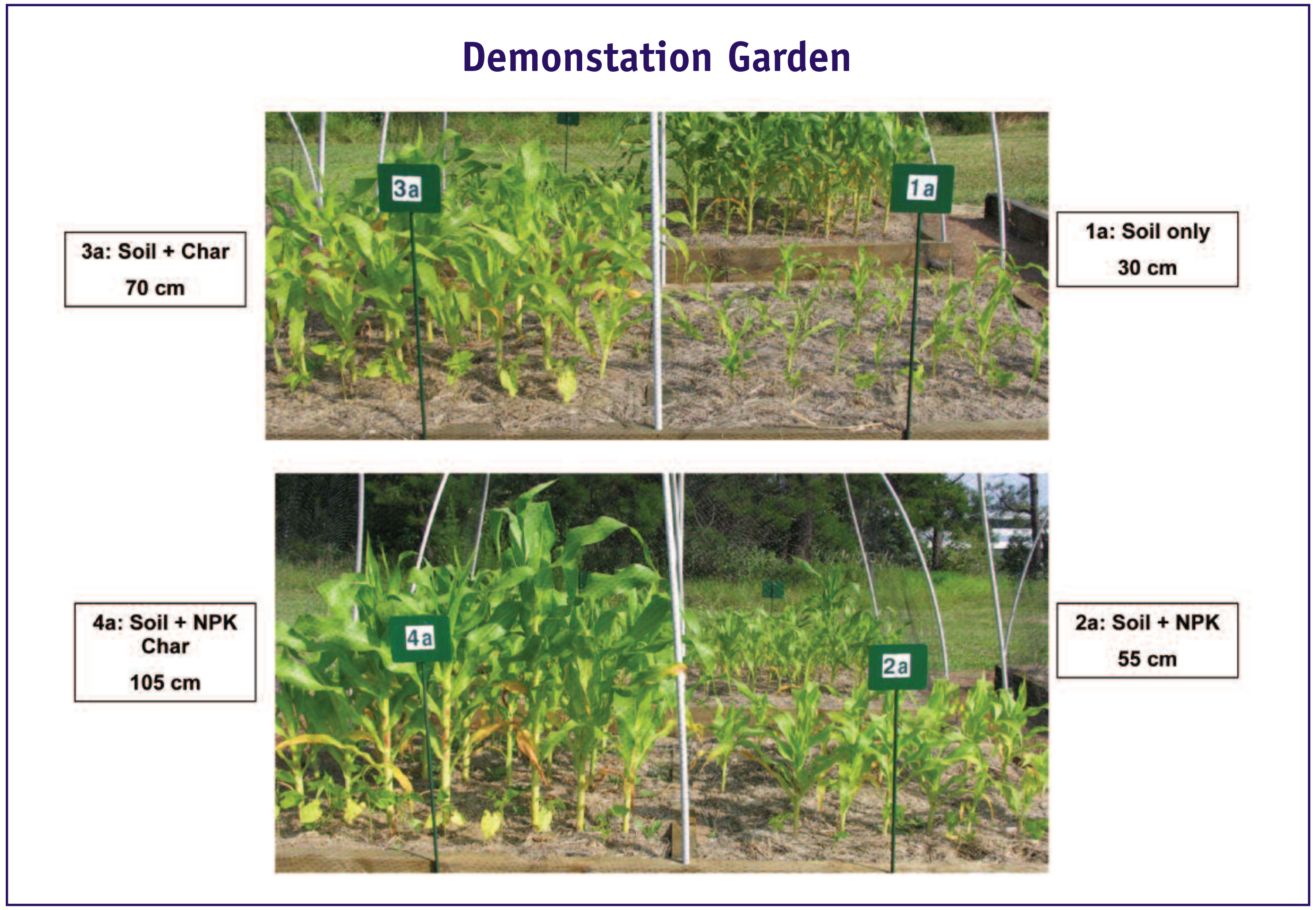

Figure 5: The demonstration garden as viewed during the Agrichar conference April 29th – May 2nd 2007.

When it comes to mitigating greenhouse gases and sequestering carbon this technology comes out in front. There is more CO2 removed from the atmosphere than is returned, even after the syngas has been utilized as a biofuel. Where other renewable technologies are promoted as 'carbon neutral', BEST's Slow Pyrolysis technology is actually 'carbon negative'. U.S. researcher Johannes Lehmann from Cornell University estimates that by the end of this century, terra preta schemes and biofuel programs could store up to 9.5 billion tons of carbon a year.

It is widely accepted by soil scientists that loss of soil carbon is linked to the declining agricultural productivity associated with widespread land degradation and reduced water quality. The Agrichar products produced from renewable biomass sources via the BEST pyrolysis process contain a stabilized form of carbon that has potential to generate a sustainable increase in soil carbon which is sorely needed in depleted, carbon-poor agricultural soils. Bio-sequestration of char has the potential to facilitate the regeneration of soil carbon levels, and hence carbon cycles, in agriculture as a whole, to pre-agricultural levels.

The bio-sequestration of carbon, in the form of char, into terrestrial systems works in harmony with the natural carbon cycles where soil has been a long term sink for carbon since its creation. This is considered a major benefit over other proposed carbon capture and sequestration methods proposed, such as geo-sequestration, which does not occur naturally in established ecosystem cycling. The preferred pathway to the rectification of greenhouse gas levels, which lead to adverse climate change, should be one which moves towards the natural order of carbon cycling.

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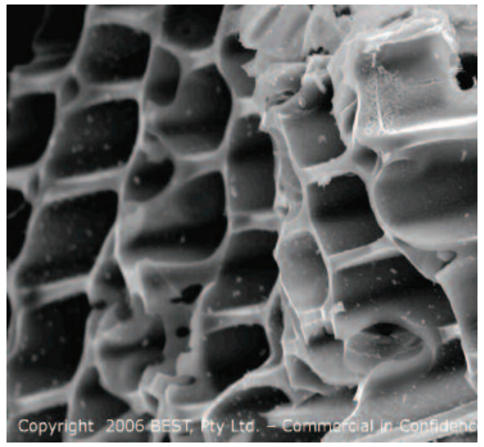

Figure 6a & b: Agrichar product.

BEST Energies & NSW Department of Primary Industries were awarded the "Sustainability Victoria Meeting the Greenhouse Challenge Award" as part of the United Nations Association of Australia World Environment Day. Their entry 'Pyrolysis for Renewable Energy & Agrichar' was entered into this new category introduced in 2007 under the theme *Melting Ice – A Hot Topic?*

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The Application of Ceramic Filters to Pyrolysis Gas Cleaning

By Andrew Startin, Madison Filter Ltd., UK

The pyrolysis process offers a number of potential advantages over conventional power generation and incineration processes. Consequently uptake of pyrolysis technology has gradually increased, most notably in Japan but also in Europe and North America.

Some of the potential benefits cited for pyrolysis, and gasification, processes are:-

- Improved efficiency/energy conversion
- Renewable energy source
- Lower capital cost
- Reduced environmental impact
- Reduced footprint.

The benefits afforded by pyrolysis will of course depend on the type and quantity of feedstock and a range of local conditions. However the drivers which determine the uptake of pyrolysis and gasification processes are strengthening as the desire to minimise residual waste increases.

The pyrolysis process typically generates syngas, char and, to a greater or lesser extent, pyrolysis oil. The char is of limited value, the syngas produced being the key output from the process. The syngas produced by pyrolysis is chiefly composed of carbon monoxide and hydrogen with smaller amounts of carbon dioxide and methane. It is used to generate steam or electricity or can even be used as a basic feedstock in the petrochemical and refining industries.

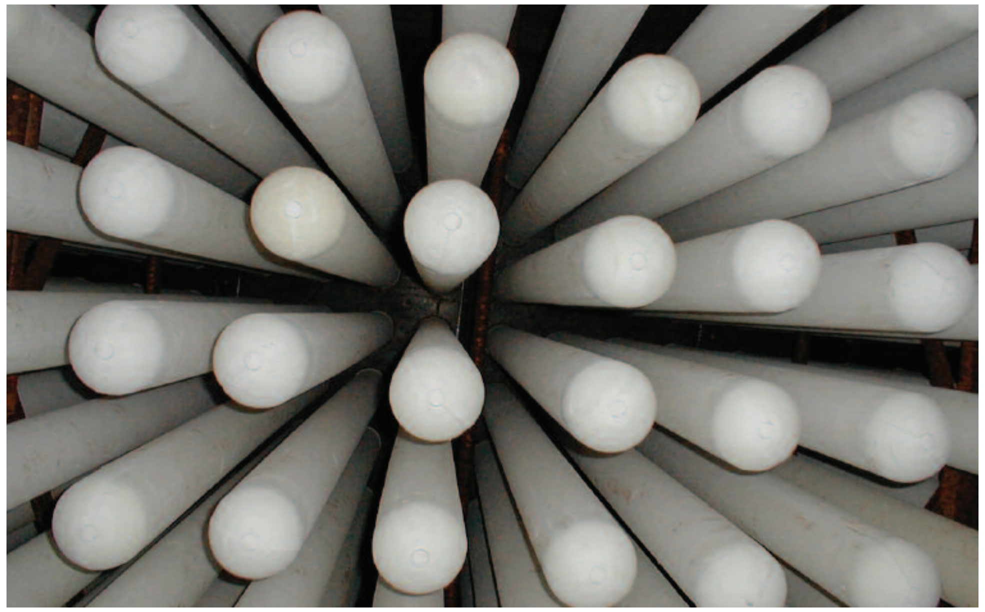

Figure 1: Cerafil ceramic filter.

The pyrolysis process is typically carried out in the temperature range from 350 – 550°C. The syngas produced is hot, dirty and carries condensable components. Downstream processes, such as boilers and engines, require clean gas to function effectively. In the case of boilers clean gas minimises tube clogging and in the case of engines erosion and frictional damage. The challenge, therefore, for gas cleaning is to remove particulates at elevated temperatures so that unnecessary gas cooling is minimised, as is the risk of condensing liquid species.

Syngas can be cleaned using a mechanical separator, such as a cyclone, or a barrier filter. Barrier filtration can be carried out by one of a family of hot gas filters, which are normally rigid and can be ceramic or metallic in nature. Metal filter media are produced from metal fibres while rigid ceramic filter media can be granular or fibrous in nature. All three basic types of filter media have found application in syngas cleaning, each having advantages or disadvantages according to the prevailing filtration conditions and operating practices of the plant as a whole.

Low density ceramic filter media, such as Cerafil® marketed by Madison Filter, offer a number of key benefits when applied to syngas cleaning:-

- Wide operational temperature range
- Extremely efficient, offering maximum protection to downstream equipment
- Excellent thermal shock properties
- Corrosion resistance
- Ease of application
- Stable performance
- Can be reverse pulse cleaned with air, inert gas or syngas.

As already stated efficient syngas filtration is crucial. In this regard Cerafil elements have been extensively tested to internationally recognised standards. In recent tests, performed according to the VDI 3926 standard, Cerafil elements exhibited clean gas particulate concentrations of < 0.4 mg/m3.

In addition to the benefits above Cerafil elements are available in a range of sizes from 1m long/ 60mm outside diameter up to 3m long/150mm outside diameter.

Filter plant installations can therefore be sized and configured according to the required operating conditions and available footprint.

Cerafil elements have, to date, been employed in over 30 pyrolysis and gasification applications, most notably in Japan. Duties range from MSW and RDF incinerator ash treatment through to full scale MSW pyrolysis. The largest of these plants, situated on Hokkaido, was commissioned in the autumn of 2002. Some plant parameters are shown in the table below.

Table 1. Plant parameters for the Hokkaido Plant.

Waste feed	Municipal solid waste
Capacity	126 tonnes/day
Element type	Cerafil XS-3000
Quantity	600
Filter area	840 m2
Cleaning pressure	8 bar
Valve opening time	300 ms

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The Cerafil filter plant is employed downstream of a rotary pyrolysis kiln and upstream of a combustion chamber. Gases from the combustion chamber pass through a steam-raising boiler prior to the flue gas treatment stage. Cerafil technology was selected for its ability to provide reliable and stable particulate removal, thus minimising upstream boiler fouling. A snapshot of plant performance is shown in Figure 2. The graph shows filtration temperature and face velocity performance for some six days for a period just after element replacement.

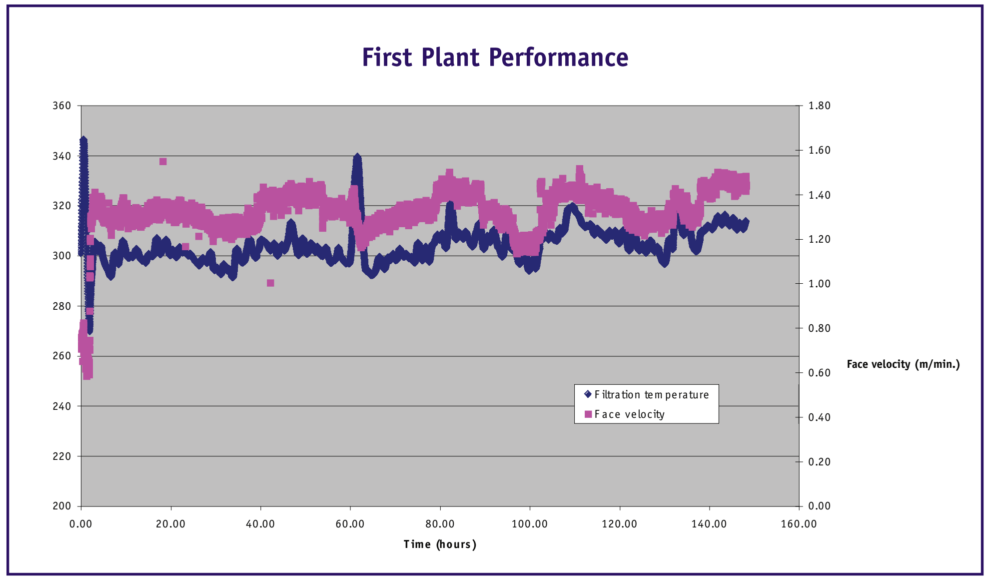

Figure 2: Filter plant performance.

During the period depicted the pressure drop across the filter plant was in the region of 3 kPa. This combination of performance variables is not untypical of low density ceramic filter performance and can be used as a guide for similar processes. What is important is that the benefits of the filter elements are utilised in providing stable hot gas filtration performance under arduous operating conditions.

Clearly given the demands of pyrolysis gas filtration applications any proposed duty needs to be carefully assessed. Filtration temperature is of paramount importance; too low and there is a risk of liquid condensation, too high risks having inorganic species in the gas phase and pushes up the capital cost of the filter housing. Other factors to be considered include the nature of the solids being collected, gas composition, the engineering of the filter vessel and the clamping and cleaning of the filter elements.

When all of the factors listed above have been considered the choice of filter media becomes clearer. The filter medium selected should be capable of delivering the right combination of filtration performance, reliability and ease of utilisation.

Cerafil low density ceramic filter elements have proved capable of fulfilling these characteristics and further plant installations are planned. Indeed Cerafil can be considered for a wide range of pyrolysis and gasification duties, both upstream and downstream of the engine or boiler in a proposed scheme.

Madison Filter Ltd. is a member of the Clear Edge Group and is present in many countries worldwide. Contact us for details of Cerafil ceramic filter elements and our wide range of filter media for liquid and dry filtration applications.

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Biomass Pyrolysis Studies at the Chemical Research Center in Hungary

By Emma Jakab, HAS, CRC, Institute of Materials and Environmental Chemistry Budapest, Hungary

The Chemical Research Centre (CRC) is a research institution maintained by the Hungarian Academy of Sciences. The Institute of Materials and Environmental Chemistry of CRC deals with the chemical problems of materials science and environmental science. The Group of Thermal Decomposition Processes has investigated the thermal decomposition of various high molecular-mass substances including polymers, coal and biomass.

The group applies various micro-scale laboratory methods to investigate the thermal behavior of various samples. Thermogravimetry/mass spectrometry (TG/MS) (Figure 1) is applied for studying the thermal decomposition processes in inert or oxidative atmospheres using low heating rates. Pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS) (Figure 2) is used for the analysis of the volatile products of fast pyrolysis.

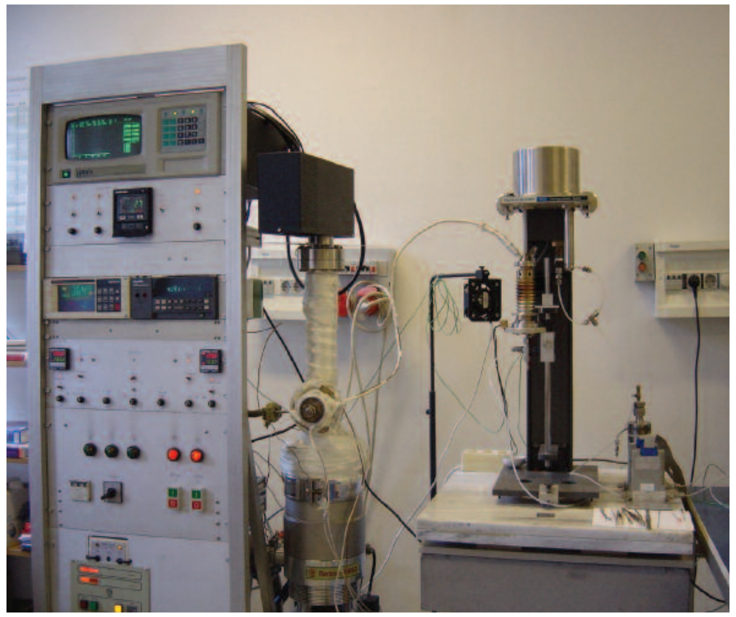

Figure 1: TG/MS system.

Figure 2: Py-GC/MS instrument.

The research group lead by Dr. G. Várhegyi has been involved in various biomass projects over the last 20 years. Early work of the group focused mainly on the thermal decomposition of cellulose and lignin. TG/MS study and the mathematical modelling of cellulose and hemicellulose pyrolysis [1, 2] were carried out in collaboration with Prof. M. J. Antal, Jr. (HNEI, University of Hawaii at Manoa, Honolulu, USA). TG/MS was also applied for studying the decomposition of various lignin and lignosulphonate samples [3, 4] in cooperation with Prof. O. Faix (BFH, Institute for Wood Chemistry and Chemical Technology of Wood, Hamburg, Germany).

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The main objectives of the biomass research are to provide analytical data about the thermal decomposition of biomass materials and study the effect of various parameters and additives on the products yields. Kinetic evaluation of the thermoanalytical data of several biomass samples has been carried out. Principal component analysis has been applied to find correlations between the thermal properties of various samples. The materials studied include biopolymers (cellulose, hemicellulose, starch, lignin), wood, herbaceous plants, biomass charcoals, agricultural residues (straw, sunflower stem) and industrial residues of plants (corn fibre, waste liquors of pulping, sugar cane bagasse). We have studied the effect of inorganic materials, catalysts, extractives, pretreatments and solvent addition on the decomposition process of various samples. Recent work has mainly focused on the thermal decomposition of wood and grass samples from energy plantations [5, 6]. In this subject, we participate in the virtual network "Centre of Competence in Thermo-Chemical Treatment of Biomass (CTCB)" led by the Forschungszentrum Karlsruhe GmbH.

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Food Additives from Bio-Oil

By Dr. Dietrich Meier, Federal Research Centre for Forestry and Forest Products, Institute for Wood Chemistry and Chemical Technology of Wood, Germany

BFH

Background

Smoking along with drying and salting are perhaps the oldest processes used to preserve foodstuffs. The smoke components have a germicidal and desiccating effect. They coagulate the proteins and therefore preserve the food. Moreover, they add aroma and color to the food making it more attractive for the consumer. In the course of the past 50 years, preservation has become less and less important. To date smoking of fish and meat is mostly done for flavoring reasons.

In Germany "freshly generated smoke" is classified as a food additive. Due to toxicological reasons it is only allowed to be used to smoke solid foodstuffs. A special regulation for smoke aromas also exists in Scandinavia. All other countries in and outside of the EU allow the unrestricted use of liquid smoke as long as the maximum content (10 µg/kg) of 3,4-benzo[a]pyrene is not exceeded.

The EC Regulation

As more and more liquid smoke aromas penetrate the European market, the legal situation has become complicated, as a lot of exceptions had to be put into force. This unsatisfactory situation will now be resolved by a new EC regulation No 2065/2003. The European Parliament and the Council established Community procedures for the safety assessment and the authorisation of smoke flavourings used or intended for use in or on foods. Under this Regulation, a smoke flavouring will only be authorised if it has been sufficiently demonstrated that it does not present risks to human health. Based on opinions established by the European Food Safety Authority (EFSA) with the help of the Panel on "Food Additives, Flavourings, Processing Aids and Materials in Contact with Food" (AFC), the European Commission will establish a list of so-called "Primary Products" (see definition below) authorised in the EU for use as such in or on foods and/or for the production of derived smoke flavourings for use in or on foods.

How does the Regulation Work?

Under the Regulation, initial applications for inclusion of a "Primary Product" in the positive list of authorised smoke flavourings have to be submitted by manufacturers to the competent authority of an EU Member State. The applications and their related dossiers are then forwarded to EFSA to undertake the safety evaluations.

EFSA has received up to now 16 applications for primary smoke flavouring products. Of the 16 applications, 2 were not valid and one was withdrawn by the applicant who was not able to provide the scientific dossier required for a proper assessment. The remaining 12 applications are currently under evaluation by EFSA's AFC Panel. After the evaluation process EFSA will inform European decision makers regarding authorising their use in foods.

What is a Primary Product?

Liquid smoke flavourings are produced by controlled thermal degradation of wood in a limited supply of oxygen (pyrolysis), subsequent condensation of the vapours and fractionation of the resulting liquid products. Most Primary Products are produced under slow pyrolysis conditions. Liquid smoke flavourings derive from smoke condensates. A typical production sequence is outlined in Figure 1.

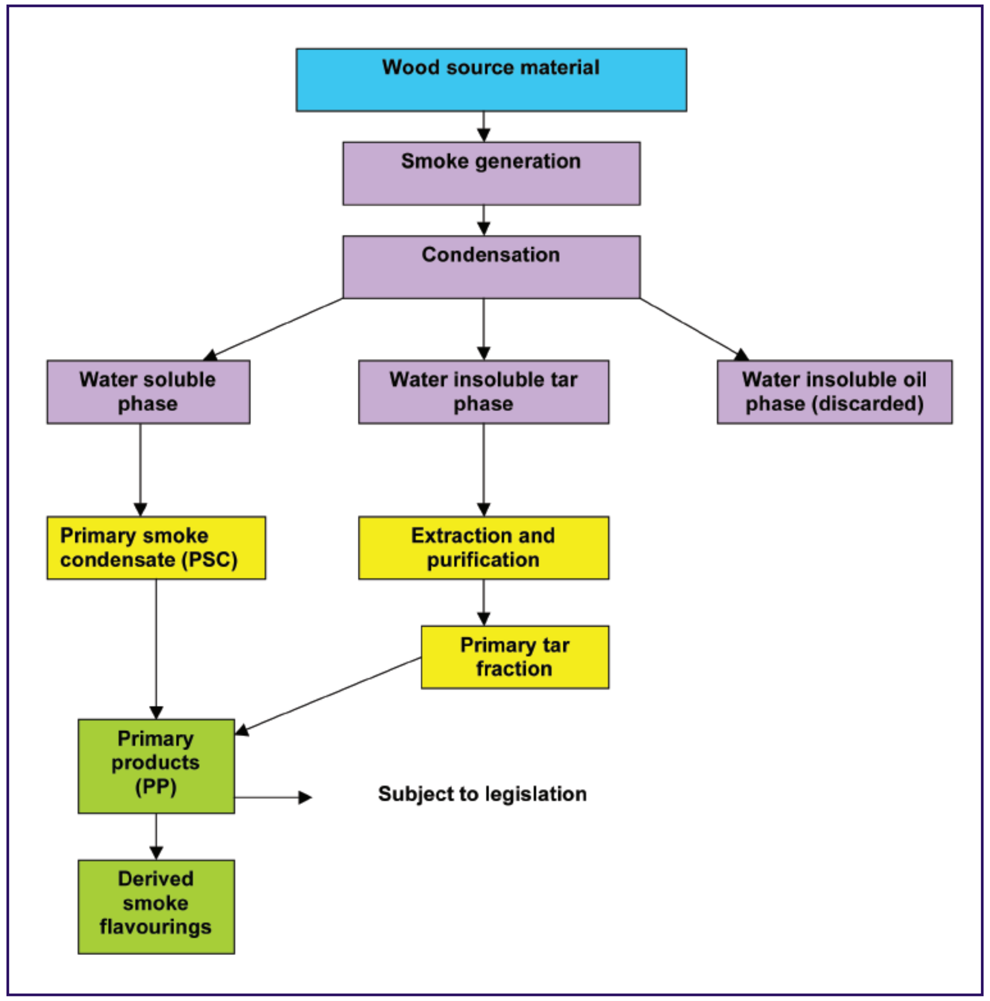

Figure 1: Typical process scheme for the production of the primary product for liquid smoke.

What Data is Required for Authorisation?

The administrative and technical data or which toxicological tests are required is available in the "Guidance from the AFC Panel on submission of a dossier on a Smoke Flavouring Primary Product for evaluation by EFSA" at *http://www.efsa.europa.eu/ en/science/afc/afc_guidance/680.html*

In summary the following information is required:

- Type of wood with details about production method of primary products and their subsequent processing
- Qualitative and quantitative analysis of the primary products and the determination of the unknown part which should be as small as possible
- Application of a validated method for sampling, identification and characterisation
- Information about the intended usage levels
- Toxicological data.

More Information

For further information, please consult the minutes of the 22nd Plenary meeting of the AFC Panel (17-19/04/2007) *http://www.efsa.europa.eu/en/science/afc/afc_meetings/afc_22nd_meeting.html*

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