

Review a pyrolysis med at low res on page 12



Steve Burne examines markets bio-oli in Europe on page 20

What is **Pyrolysis Liquid?**

Pyrolysis liquid is referred to by many names including pyrolysis liquid, pyrolysis oil, bio-crude-oil, bio-oil, bio-fuel-oil, pyroligneous tar, pyroligneous acid, wood liquids, wood oil, liquid smoke, wood distillates and liquid wood. It is an oil as it is combustible, and renewable hence the use of the term 'bio'.

Appearance

Pyrolysis liquid typically is a dark brown free flowing liquid. Depending upon the initial feedstock and the mode of fast pyrolysis, the colour can be almost black through dark red-brown to dark green, its colour being influenced by micro-carbon in the liquid and the elemental composition. High nitrogen contents in the liquid can give it a dark green tinge. from low molecular weight and volatile formaldehyde and acetic acid to complex high molecular weight phenols and anhydrosugars.

Heating Value

Pyrolysis liquid has a heating value of nearly half that of a conventional fuel oil – typically 16-18 MJ/kg. The liquid contains varying quantities of water which forms a stable single phase mixture, ranging from about 15 wt% to an upper limit of about 40 wt% water, depending on how it was produced and subsequently collected. Pyrolysis liquids can tolerate the addition of some water, but there is a limit to the amount of water which can be added to the liquid before phase separation occurs, in other words the liquid cannot be dissolved in water.

continued on page 11

Odour

The liquid has a distinctive odour – an acrid smoky smell which can irritate the eyes if exposed for a prolonged period to the liquids. The liquid contains several hundred different chemicals in widely varying proportions, ranging

> The fourth PyNE Group Network meeting in Hamburg, Germany. For the fuller picture of events and feedback, see page 2.



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Pyrolysis

Network

Europe.

for

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Meeting Progress

The fourth PyNE Network Meeting took place in Hamburg, Germany from 21-25 June 1997. A review of the Network activities including country reports were discussed and three technical visits were made to:



Dietrich Meier (left) with PvNE Co-ordinators Claire Humphreys and Tony Bridgwater.

1. Institute of Wood Chemistry to see the 5 kg/h fluid bed fast pyrolysis unit;

2. University of Hamburg to see fluid bed pyrolysis of plastics;

3. Chemviron Carbon, Gottingen, to see the production of charcoal and chemicals. (see page 21).

Observers are very welcome to participate in PyNE meetings.

If you would like to attend the next meeting of PyNE, please contact your country representative (see back page for details) or Claire Humphreys.

The World Sustainable Energy Trade Fair

This event took place in Amsterdam,

27-29 May, 1997. The aims of this event included the display of technologies sufficiently mature to be the basis for dynamic new industries, in order to reach sustainability and discuss the means to accelerate the introduction of these technologies into markets all over the world.

Both an exhibition and a congress took place which included the following themes:

- Renewable Energy Forum
- Marketing & Market Introduction
- Utilities & Infrastructure

- Waste-to-Energy
- Marketing & Market Introduction
- Utilities & Infrastructure
- Sustainable Transport
- Marketing & Market Introduction
- Utilities & Infrastructure
- Global Finance for Sustainable Energy
- Export Market Overview

The leading companies from all over the world presented the latest technology and equipment in the fields of renewable energy, waste-toenergy and sustainable transport.

14th International Conference on Fluidised Bed Combustion

This conference was held in Vancouver, Canada, 11-14 May, 1997. The aim of this conference was to promote the exchange of operating, economic and scientific information pertaining to all aspects of fluidised-bed combustion.

The technical program of the conference included approximately 150 oral presentations addressing a wide range of FCB related subjects.

The conference program included two workshops focusing on "Biomass Utilisation" and "Waste Fuels Firing". Each workshop included presentation of 12-15 papers relevant to the workshop topics in a format to allow increased discussion and audience participation.

The proceedings were edited by Fernando Preto from the Canmet Energy Technology Centre in two proceedings books published by The American Society of Mechanical Engineers.



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Gasification and Pyrolysis of Biomass

By Iannis Boukis, CRES, Greece

This conference took place in Stuttgart, Germany, 9-11 April 1997. Over 55

presentations were made including posters. The main results, as far as the evolution of pyrolysis technology is concerned, are briefly summarised.

Fundamentals

Dr D. Meier (Institute for Wood Chemistry, Hamburg) made a thorough review of the chemical nature of pyrolysis liquids identifying the major functional groups. A procedure for physical and chemical analysis based on produce fractionation was proposed.

Applied Research BTG gave preliminary results from its rotating cone pyrolysis reactor (50 kg/h) developed in co-operation with Royal Schelde (NL).

DMT-FuelTec described upgrading pyrolysis liquids in the IGOR Coal Hydrogenation Process.

Applications

Dr. D. Radlein from the Canadian Company is investigating the utilisation of pyrolysis liquids for the production of fertilisers and soil conditioners. He forecast a huge future potential for deriving sugar derivatives (levoglucosenone, levoglucosan, etc.) as well as wood smoke flavours from pyrolysis liquids. He described the DynaMotive product Bio-Lime®, for controlling emissions from coal fired plant.

Chemistry, Energy and Environment 3

This conference was held in Estoril, Portugal, 25-28 May, 1997.

The third Chemistry, Energy and Environment focused on:

- energy, storage and conservation for the 21st century and the relationship of these with environmental concerns,
- the importance of chemistry in the production of energy in an environmentally friendly manner,
- definition of strategies for energy and environment in the chemistry curriculum.

Topics included:

- Chemistry Friend or Foe of the Environment?
- Catalysis in the Service of the Environment
- The Challenge of the Environmentally Friendly Production of Energy
- Hydrogen as an Energy Source
- Renewal Energy and Water Production
- Energy Sources For 2000 and Beyond

The proceedings will be edited by Cesar Sequeira (Lisbon University), and John Moffat, (University of Waterloo), and will be published by The Royal Society of Chemistry, UK.



Tony Bridgwater & Martin Kaltschmitt – conference organisers

S. Gust of the Finnish refinery Neste Oy presented results from burning pyrolysis liquids in the small-to-medium. The results are considered promising, however better emission control is required.

J. Leech described the successful use of crude pyrolysis liquids in dual fuel, medium speed diesel engine. A total of 160 h of operation based on a 95:5 pyrolysis oil: diesel mixture (by energy) were reported.

Dr. P. Patnaik of Orenda Aerospace reported the first results from pyrolysis liquids firing in a 2.5 MWe gas turbine, jointly developed by Orenda and its Ukranian subsidiary Mashproekt. Initial testing has revealed smooth combustion in the two silo-type turbine burners.

C. Rossi (ENEL) and Dr. R. Graham (ENSYN) reported on the progress on the ENSYN 650 kg/h fast pyrolysis plan, undergoing an acceptance test in Bastardo, Umbria. The plant is expected to be in full operation in the second quarter of 1997.

Prof. A. V. Bridgwater concluded the pyrolysis sections of the conference follows:

- the need for further fundamental work needs to be stressed,
- stabilisation seems to be imperative for pyrolysis liquids quality improvement,
- applications requiring minimum modifications should be developed,
- long-term testing on heat and power applications for pyrolysis liquids is needed,
- the concept of a bio-refinery to produce fuels and chemicals are produced simultaneously should be investigated,
- improved characterisation and testing methods are required.

Chemicals and Materials from Bio-oil

By Desmond Radlein, Resource Transforms International Ltd., Canada



Desmond Radlein at the PyNE group meeting, May 1997

In part one of a two part feature, Desmond Radlein examines chemicals and materials from bio-oil.

Most of the current research effort on utilisation of bio-oil from fast pyrolysis of biomass is targeted at fuel applications. However, at the present time such applications are only potentially viable, i.e. without subsidy, for certain waste feedstocks.

In the short term, widespread industrial production of bio-oil will depend on its utilisation for the manufacture of chemicals and materials of higher added value than fuels.

RTI Ltd. has been carrying out research and development towards this goal and some progress has been made. The 15 kg/h fast pyrolysis unit at RTI is shown in Figure 1.

Some of the applications so far identified include production of specific chemical synthons, flavour chemicals, organic fertilizers,

fuel additives, additives for pollution control, boiler fuels and diesel fuels. We envisage a biomass refinery, analogous to a petroleum refinery,

but in which the distinctive character of bio-oil is recognised and it is refined into useful products.



Figure 2. Idealised Phase Stability diagram of Bio-oil and Water.

Physico-Chemical Character of Bio-oil

Fast pyrolysis "oils" are complex mixtures of the degradation products of ligno-cellulose. In the past a distinction has been made between the so-called A-tars and B-tars. The former are the sedimentation tars associated with slow pyrolysis. They are mainly secondary pyrolysis products, are relatively oxygen poor, insoluble in water and contain large amounts of simple phenols, hydrocarbons, etc. The latter, currently referred to as "bio-oil", are highly oxygenated and increase in yield under fast pyrolysis conditions indicating that they are principally primary pyrolysis products which directly reflect the character of the feedstock from which they are derived.

It is by now well known that bio-oils are not similar to the familiar petroleum derived oils. The high oxygen content imparts a hydrophilic

> nature rather than a hydrophobic one so that it has poor miscibility with hydrocarbon solvents. Indeed, it is maintained as a liquid only on account of the presence of water in quantities typically in the range from 15 to 25 wt %. The molecular components originate from the lignin as well as from the cellulosic components of the feedstock and vary in size from simple low molecular weight compounds to large fragments with molecular weights over 1000.

Besides hydroxyl and methoxyl groups, the oxygen present is also associated with functionalities like carbonyl and carboxyl, which render the oils reactive, thermally unstable and susceptible to aging on storage. Thus conventional separation techniques like distillation are not applicable. Thus non-fuel utilisation of bio-oil requires identification of novel products and the development of new processes for their separation or production. A significant development and marketing effort is required if these ideas are to come to fruition.

Separation Methods

The recovery of chemicals requires that effective separation schemes be available. As indicated earlier, conventional methods like distillation do not appear to be useful or feasible. The simplest approach is to separate the hydrophilic and hydrophobic fractions by a water induced phase separation. A qualitative phase diagram of the behaviour under water addition is illustrated in Figure 2.

It has been demonstrated previously [1], that the precipitated hydrophobic component is derived principally, although not exclusively, from lignin. Thus it is usefully characterised as pyrolytic lignin and as such may be utilised in many known lignin applications. These should preferably be chosen to take advantage of its unique characteristics. For example it is more degraded, i.e. has a lower average molecular weight and a greater ratio of phenolic to methoxyl groups, than pulping based lignins.

A disadvantage of this phase separation method is the dilution of the aqueous phase so that subsequent recovery of water soluble chemicals may require expensive evaporation of water. A sequential selective solvent extraction of useful components would be most desirable. An example is the separation of neutral and phenolic fraction with ethyl acetate [2].

However a complete generally applicable scheme has yet to be identified. Other methods for the recovery of specific compounds or chemical classes, including selective adsorption, membrane separation and continuous chromatography, have also been investigated [3].

continued overleaf...



Figure 1. RTI 15 Kg/h Pilot Plant.

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continued from previous page.





Recovery of Specific Chemicals

In order to recover specific chemicals it is necessary that these be present in the bio-oil in large enough quantities to make their recovery economic. For normal ligno-cellulosic feedstocks the number of possible candidates is not very large, the principal candidates being hydroxyacetaldehyde (glycolaldehyde), acetic acid, formic acid, levoglucosan and levoalucosenone.

Hydroxyacetaldehyde, CH₂OH-CHO, is produced by fragmentation reactions of cellulose and hemicellulose catalyzed by traces of alkali salts. It is usually the most abundant single compound present in bio-oil from untreated wood. Yields up to 17% from cellulose, have been reported [4], while more generally, yields from wood are roughly proportional to the holocellulose (cellulose plus hemicellulose) content.

It is chemically similar in many respects to glyoxal and to formaldehyde. Its efficient recovery is difficult although a method has been patented by Red Arrow Products Co. Inc. for its extraction from bio-oil using methylene chloride [5]. Our own current research indicates that the pure compound can be produced at about \$5/kg.

This is too expensive as a glyoxal replacement, although potential markets as an organic synthon exist, thus applications in which low purity aqueous mixtures with other aldehydes and/or acids are adequate become more attractive. Examples include the production of hydrazones as oxygen scavengers in boiler water systems, applications in reducing thermal and light-induced brightness reversion in lignincontaining pulps, and elimination of hydrogen sulfide by using water-in-oil emulsions.



n=0. Cellobiosan n=1: Cellotriosan

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The second part of this feature will be published in the March 1998 Edition.

enhanced by traces of acidic catalysts. Its virtues as a versatile chemical building block have been well documented [6]. For example it is a useful chiral synthon owing to the internal acetal ring which renders the molecule structurally rigid so that a high degree of stereochemical control is possible. Other applications include the production of specialty polymers and resins, glucoside surfactants, and unhydrolyzable polyglucoses among many others.

Levoglucosan (1,6-Anhydro-ß-D-Glucopyranose)

may be regarded as the monomer of cellulose.

i.e. de-mineralized feedstocks, and is further

Its yield is enhanced from clean,

On subsequent hydrolysis, fermentable hexoses are obtained in yields that exceed the identified anhydrosugar [7]. Indeed the pyrolytic approach to the production of fermentation ethanol from ligno-cellulose appears to be competitive with the more well known acid and enzymatic hydrolyses.

Levoglucosenone (6,8-dioxabicyclo[3.2.1]oct-2en-4-one) is a doubly dehydrated anhydrosugar which is also a useful chiral synthon, possessing unique properties and reactivity due to the presence of the enone system. We have been able to obtain up to 24 wt % from cellulose using fluidised bed pyrolysis, equivalent to a yield of 31 wt % based on the glucosan content of cellulose. Furthermore its ease of recovery by distillation suggests that it will be possible to produce this, currently very expensive, chemical even more cheaply than levoglucosan.

Applications in the scientific and patent literature include the synthesis of antibiotics and immunosuppressive agents, production of pheromones and flavour chemicals like whisky lactones, conversion to rare sugars like D-altrose and D-allose and use as a precursor for C-glycosides, [6].

Anhydro-Oligosaccharides: Anhydro-oligomeric mixtures can be produced by pyrolysis of cellulosics under conditions of extremely rapid heating and guenching. We have obtained yields up to 25 wt % of mixtures with DP (degree of polymerisation) of 2-8. Such mixtures may find a use in dextrin formulations. However isolation of the individual molecules is likely to be expensive.



Incentives Available for the Energetic use of Biomass in **European Countries**

By Max Lauer and Josef Spitzer, Joanneum Research, Austria.

The energetic use of biomass under present market conditions in most applications is not economical for, either the user or investor compared to fossil fuels. On the other hand biomass has significant advantages from a socio-economic and environmental point of view. So the interest in the energetic use of biomass has increased in many countries. This has lead to widely different incentives for increasing the use of biomass.

These can be categorised under:

- National policies
- Biomass programmes (and complementary support mechanism)
- Tax relief for energy from biomass and energy taxes on non renewable energy sources
- Grants for capital investment
- Subsidies for electricity production.

National policies

There is a wide variation in the national policies in European countries. A few countries have long range policies, programmes and complementary support mechanisms in place. Finland, Denmark and Austria have detailed policy structures for agricultural and forestry residues as well as for some sectors of the biomass industry.

However, in a number of countries, there are no stated national (although sometimes regional or local) policies specifically for bioenergy. Lack of national policies for the development of biomass, or inadequate national policies, was stated to be a problem by Greece, UK, Portugal, Spain and the Netherlands. In many countries there are policies for renewable energies which include biomass and bioenergy, but the priority given is unclear. For example, the UK has a policy on renewable energy and targets for installing renewable energy power generation capacity, but there are no explicit targets for bioenergy. Indeed, few countries have set targets for increased use of bioenergy. The exceptions are Italy and Finland, which have set targets for supplying 1.5 % and 25 %, respectively, of national energy needs from biomass by the year 2000.

Biomass programmes

Most countries have implemented national biomass programmes or at least co-ordinated regional biomass programmes (Austria, Denmark, Germany, Greece, Netherlands, Portugal, Spain, Sweden and the United Kingdom). National biomass research and development programmes are implemented in Austria, Finland and France Belgium has only regional programmes and Ireland has no biomass programme at all, but a Renewables Energy Information Centre has recently been established.

Tax relief and energy taxes

Tax relief for renewable energies and energy taxes for fossil (and partly also nuclear) derived energies are to balance the external economic effects of the use of non-sustainable energy. In some countries these economic policy instruments are used in a very effective way. The application of energy taxes is reported from Austria, Belgium, Denmark, Finland, the Netherlands and Sweden. But other countries also have taxation systems with effects on the use of biomass (e.g. Italy).

Grants for capital investment

Grants for capital investment are given in most countries but aimed at very different fields of application.

Subsidies for electricity production from biomass

No subsidies for electricity production are so fail reported from Austria, Belgium, Finland and Sweden. In the other countries subsidies are given in different ways. In Italy for example, a relatively high price for electricity from biomass is paid by the national utility, which led to a boom in construction of biomass power plants.

This contribution is based on information taken from the Final Report of Phase I of AFB-nett, to EU-ALTENER, by ETSU, Harwell, Didcot, Oxfordshire.



By Morten Fossum, SINTEF, Norway



The abbreviation **SINTEF** stands (in Norwegian) for "The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology".

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Tel: +47 73.59.25.14 Fax: +47 73.59.28.89. Email: morten.fossum@energy.sintef.no **The SINTEF Group** performs contract research and development for industry and the public sector in the fields of technology and the natural and social sciences. With 2000 employees and an annual turnover of NOK 1.4 billion (approx. ECU 172 million), SINTEF is the largest independent research organisation in Scandinavia. Industrial and public sector contracts account for more than 90% of the turnover. SINTEF operates in close collaboration with the Norwegian University of Science and Technology (NTNU) on the basis of experts working together on projects, sharing laboratories and equipment. We also co-operate with the University of Oslo.

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SINTEF Thermal Energy and Hydropower is one of six divisions within SINTEF Energy, where the research is organised in the following specialist groups with related activities:

Energy and Process Engineering

- Industrial heat engineering (heat exchangers, drying technologies, evaporation technologies, granulation etc.).
- Energy-technology equipment for energy conversion e.g. gas turbines, compressors, pumps and heat exchangers, and systems using these components.
- Multi-phase flow in components.
- Systems industrial processes including the regulation and monitoring of these, system engineering and life cycle analysis.
- Hydraulic and pneumatic components and systems.

Combustion and Environment

- Research into the basic nature of combustion, the formation of polluting components and reduction of these, and safety and energy-efficiency in the combustion process.
- Combustion of solid, liquid and gaseous fuels, e.g. bio-fuels, waste, coal, oil and natural gas.
- Deflagration/detonation in shock tubes and other geometries requiring evaluation in respect of material integrity and safety.
- Industrial emissions measuring and development of gas cleaning equipment.
- Biomass activities

The activity on biomass at SINTEF Thermal Energy and Hydropower consists of both contract R&D projects for industry and the public sector and more fundamental studies in the form of PhD activities funded by the Government. The range of activities are given by the following examples:

R&D activities:

- Development of wood stoves.
- Design and development of a pyrolysis plant for the production of tar and charcoal.
- Use of biomass in the Fe-Si industry.
- Development of combustion technology for waste.



By Professor Zoulalain, Université Henri Poincar, France.

The research group **"Génie des Prodédés"** of LERMAB was created in 1974 at the "Université de Technologie de Compiégne". From 1974 to 1985, the research activities concerned the development of methodologies and the analysis of heterogeneous reactions for the chemical and petrochemical industries. Several studies concerned the valorisation of natural mono and polysaccharides by hydrogenolysis with solid catalysts.



The "ENSTIB lab".

For further information:

ENSTIB, LERMAB – 27 rue du Merle Blanc – B.P. 1041 – 88051 EPINAL – FRANCE Research Group: Génie des Prodédés Head of the group: Professor A Zoulalian Tel: +33 29 81 11 50 Fax: +33 29 34 09 76 The research group was subsequently transferred to the University of Nancy and collaboration initiated with the ENSTIB institution. The research now covers two fields:

1) Process engineering methodology applied to wood materials.

Three studies are in progress involving four researchers:

- convective wood drying with recirculation of moist air,
- design and development of wood cement composites,
- combustion of wood residues.

2) Heterogeneous chemical reactions

A number of projects are underway which involve six researchers:

- upgrading of biomass residues by hydrogenolysis, pyrolysis and gasification to produce gas or liquid fuels,
- pyrolysis of solid polymer wastes,
- absorption or reaction of gaseous pollutants in flue gas such as acid gases (HCl, SO₂, NOx) and polyaromatic hydrocarbons,
- elimination of liquid pollutants in industrial waste water such as aromatic hydrocarbons and reductive salts, by catalytic and photo-catalytic reactions.

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New Member PEARSE BUCKLEY graduated as a Mechanical Engineer. After 13 years in Canada, he returned to Ireland to study short rotation forestry for energy. As a research officer in Trinity College he has completed studies on the market for energy from short rotation forestry in Ireland and an investigation of pyrolysis for the treatment of animal manure. He is currently looking at pyrolysis in relation to the product from rendering plants.

The PyNE Network would like to welcome Pearse to the group who will now be the country representative for Ireland.



Six centuries of history http://www.ucl.ac.be

The Université Catholique de Louvain was established on December 9, 1425, by a papal bull issued by Pope Martin V. In 1797 the University was abolished as a result of French occupation and forced to remain closed until 1817 when it reopened as a state university.

Following the foundation of the Kingdom of Belgium in 1830, the "Free" Catholic University was re-established, first in Malines in 1834, and the following year in Louvain.

The University split along language lines as a result of political turmoil in the late 1960s. A law recognising separate Flemish-speaking and French-speaking universities was passed in 1970. The former remained in Louvain while the latter moved to a new location on the outskirts of Ottignies. This new campus became the town of Louvainla-Neuve. Between 1972 and 1979, nine faculties (schools) gradually moved to Louvainla-Neuve. There are 5000 members of staff, 21000 students in 10 different faculties, 50 departments and 200 research units.

Unite de catalyse et chimie des materiaux divises (CATA)

http://www.agro.ucl.ac.be/cata-pub/www/cata.html

Under the leadership of Professor Bernard Delmon and Professor Paul Grange, the UCL-CATA laboratory is among the strongest university catalysis research centres in the world. The activities cover all aspects of catalysis, from fundamental to applied research in different topics including selective and total oxidation, hydrotreating, basic catalysis, zeolites and pillared clays. In addition, CATA has been involved since the early 1980s in many European programmes for the valorisation of biomass and solid waste derived products, especially liquids produced by fast pyrolysis of biomass. The main financing sources are Regional, National and European programmes, as well as industrial contracts. UCL-CATA co-operates with European, American and Japanese universities and with major companies such as BP, Solvay, Fina, Rhône Poulenc, Repsol. CATA organises the International Symposium on Scientific Bases for the Preparation of Heterogeneous Catalysts every four years as well as other important congresses and symposia.

UCL-CATA is well equipped for catalyst development and the evaluation of catalytic activity and selectivity. More than 30 different catalyst testing units are available (batch, flow, micro-probe, fixed-bed and others). CATA owns all the necessary equipments for the characterisation of catalysts and other solids such as BET, XPS, SEM, AFM, X-Ray diffraction, Raman, FTIR-DRIFT, TPD. It also owns all necessary equipment for product analysis such as GC, GC-MS, HPLC, HPLC-MS, FTIR and high resolution NMR. In addition CATA has access to high resolution NMR and GC-MS laboratories located in other UCL research units.



Upgrading and characterisation of pyrolysis liquids

During the past 15 years UCL-CATA has been involved in the valorisation and analysis of biomass and natural resources derived liquids under the leadership of Dr. Rosanna Maggi. Different chemical, catalytic and physical upgrading processes are currently studied including catalytic hydrodeoxygenation and vapour phase cracking.

All catalysts are specially developed and laboratory made. For these purposes three dedicated catalyst testing units have been purchased: a 1 l high pressure autoclave (from Sotelem); a 200 ml/h two steps high pressure fixed-bed hydrotreater (from Autoclave Engineers); and an atmospheric pressure fixed-bed micro-probe cracker (laboratory made).



Specially dedicated two steps floor high pressure hydrotreater

What is Pyrolysis Liquid? continued from front page.

If two phases are formed, one is highly viscous containing the water insoluble chemicals [typically the lignin fraction] and the other is a very fluid, watery phase. This watery phase contains the water soluble aldehydes, sugars, some phenols and ketones.

Density

The density of the liquid is very high at around 1.2 kg/litre compared to light fuel at around 0.85 kg/litre. This means that the liquid has about 42% of the energy content of fuel oil on a weight basis, but 61% on a volumetric basis. This has implications on the design and specification of equipment such as pumps.

Table 1: Typical characteristics of wood derived pyrolysis liquid		
Physical property		Typical value
Moisture content		20%
рН		2.5
Specific gravity		1.20
Elemental analysis	С	56.4%
	Н	6.
	0	37.3%
	N	0.1%
	S	<0.1%
	Ash	0.1%
HHV as produced (depen	ds on moisture)	16-18 MJ/kg
		20-23 MJ/litre
Viscosity (at 40°C and 2	5% water)	40-100 cp
Solids (char)		1%
Vacuum distillation		max. 50% as liquid degrades

Distillation

Pyrolysis liquids cannot be vapourised once they have been recovered from the vapour phase. If the liquid is heated to 100°C or more to try to remove water or distil off lighter fractions, it rapidly reacts and produces a char residue of around 50wt% of the original liquid and some distillate containing secondary products and water. The liquid is, therefore, chemically unstable, and this effect increases with heating, so it is preferable to store the liquid at room temperature. These changes do occur at room temperature, but much more slowly and can be accommodated in a commercial application.

A summary of representative properties is given in Table 1.

Summary

In summary, pyrolysis liquid or bio-oil is dark red-brown, is free flowing at room temperature and has a strong acrid or smoky odour which may be mildly irritating to some individuals. The liquid can be used as a substitute for conventional liquids in many static applications and contains a wide variety of chemicals. The liquid cannot be vapourised like a conventional fossil fuel and heating above 100°C causes irreversible chemical reaction.

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Review by Stefan Czernik (NREL) of report (NREL/TP-430-22739) by James P. Diebold (Thermalchemie), USA



James Diebold

Stefan Czernik

Introduction

The scale-up of biomass fast pyrolysis systems for production of liquids will expose an increasingly large number of personnel to potential health hazards. Although fast pyrolysis technologies that are optimised for high yields of liquids are relatively new, slow pyrolysis processes have been used for many centuries to produce charcoal and liquid by-products such as food preservatives and flavours, and wood

This summary is taken from an in-depth review of the health and safety aspects of pyrolysis liquids that was carried out for the IEA Bioenergy Pyrolysis Activity, NREL and Natural Resources Canada.

It is published by NREL. (NREL/TP-430-22739)

distillates. Although wood smoke, wood distillates and fast pyrolysis oils have a different quantitative composition, they contain a large number of the same components. Thus the existing studies on the hazards of acute and long-term exposure to traditional wood pyrolysis liquids can be useful in assessing the health hazards of the oils.

Noxious components

The toxicity of oils is a function of their composition, which depends on the process and its conditions, and the feedstock. The main classes of chemicals

and the feedstock. The main classes of chemicals in biomass pyrolysis liquids are: organic acids, aldehydes, ketones, esters, phenolics, and furans. The total amount of aromatic hydrocarbons in the oils generated below 550° is only 0.06 wt. %. Based on the known amounts of specific compounds in the oils and their permissible exposure levels (PEL) established by the U.S. Occupational Safety and Health Administration, it can be concluded that aldehydes (formaldehyde, acrolein), furans (furfural alcohol), and phenols (phenol, 2,3 – dimethyl phenol, 1,4-dihydroxy phenol) pose the greatest toxic threat. The projected acute oral toxicity of the oils would be around 700 mg/kg of body weight.

Toxicity Tests

Both chronic and acute toxicity tests have been performed on fast pyrolysis oils generated in the NREL vortex reactor system. The chronic toxicity of the oils is unclear, with one study indicating no tumor promoting ability and the other study showing mutagenicity. While the amount of polycyclic aromatic hydrocarbons in fast pyrolysis oils is very small, the presence of formaldehyde and acetaldehyde could cause dangerous longterm effects. The acute toxicity tests showed a low effect of the oils to the skin with no abnormalities observed after contact after 15 days. Eyes, however, are very sensitive to pyrolysis liquids with probable severe corneal damage resulting from even low exposure. Such a result is not surprising considering the high content of organic acids, aldehydes, and phenols. Inhalation tests found that damage results from much higher levels than that causing eye irritation and possible damage.

Conclusion

Based on these acute exposures tests it is recommended that the Material Safety Data Sheet (MSDS) contain a warning label stating that fast pyrolysis oils are a hazardous substance to the eyes and to inhalation exposure, but not to dermal exposure. The oils can be handled safely using personnel protective gear, such as rubber gloves, goggles, and protective clothing.

Development of the Shell Hydrothermal Upgrading Process

By Frans Goudriaan and J.E. Naber, BIOFUEL, The Netherlands

as "Bio-crude"

The gross thermal

process is about 90%

(Lower Heating Value

(LHV) of bio-crude

LHV of feedstock).

After allowance for

requirement of the

thermal efficiency is

depending on the

process the net

the energy

75 - 85 %

process configuration.

efficiency of the

The HTU process

Hydrothermal upgrading (HTU) for the liquefaction of biomass was investigated at the Shell Research Laboratory at Amsterdam from 1981 to 1989. The process was demonstrated in a continuous bench scale unit with a throughput of some 1 kg/h of wood (dry basis). The essence of the HTU process is to contact the biomass with liquid water at high temperature and high pressure at conditions indicated in Table 1. The product is a liquid hydrocarbon referred to



Figure 1.

Table 1

Feed

Con

Proc

Feedstocks

A key feature of HTU is the use of wet biomass streams that do not require drying. Feedstocks range from wood chips to industrial organic waste streams and sewage sludge.

Products

The bio-crude product is an organic oil which separates from the process water. Its oxygen content is 10-15 %w. Therefore the LHV approaches that of comparable fossil fuels. The bio-crude is similar to the residue of atmospheric distillation of crude mineral oil, but its sulphur and nitrogen content are very low. The product can be stored and transported. The properties are summarised in Table 2 and compared to other liquid fuels. By-products are organics dissolved in the process water, like ethanol, methanol and acetic acid, and the minor amount of gas that is formed containing carbon monoxide, hydrogen and methane.

Applications

The bio-crude seems suitable for combustion, for use in medium-speed diesel engines and thus for

Table 2

Fuel	Wood	Fast Pyrolysis Oil	HTU Biocrude
Moisture, %wt	35.0	26.0	0.0
Density, kg/l	0.23	1.18	1.02
Composition, %wt dry basis			
С	48.2	57.4	75.4
Н	6.4	6.3	6.3
0	45.4	36.3	<18.0
LHV, MJ/kg dry basis	17.82	22.1	>30.3
Water-miscible	-	yes	no

the generation of electricity and heat. Use in gas turbines would require further studies. Laboratory studies have demonstrated that bio-crude can be catalytically hyrodeoxygenated giving a fully distillable product and a very good diesel fraction.

Economics

Economic analyses of the HTU process for the liquefaction of wood have been performed both by Shell and by Stork-Comprimo (now Stork Engineers and Contractors). They showed that the costs of HTU, gasification and pyrolysis are in the same bracket. Figure 1 shows the cost of bio-crude from wood. The long processing cost is expected to at least halve due to economy of scale and learning effect.

Present status

A demonstration plant is planned for industrial waste which is expected to take about $2\frac{1}{2}$ years. An additional $2\frac{1}{2}$ years of R&D is required before a large-scale plant for the conversion of wood can be designed.



Frans Goudriaan

Comparison with pyrolysis

The most important differences between HTU and pyrolysis are:

- HTU has more feedstock flexibility
- HTU requires less feedstock pre-treatment particularly comminution and drying
- Process complexity of HTU is greater
- Some HTU product properties are improved - see Table 2 below.

litions	liquid water
	temperature: 300-350°C
	pressure: 120-180 bar
	residence time: 5-15 min.
ucts	50%wt bio-crude
	(10-15%wt oxygen)
	30%wt gas (> $30%$ wt co ₂)
	15%wt water

biomass (40%w oxygen)

References F. Goudriaan and D.G.R. Peferon Liquid fuels from biomass via a hydrothermal process", Chem. Eng. Sci., 45, No.8, (1990) 2729-2734

5%wt dissolved organics

F. Goudriaan, P.F.A. van Grinsven and J.E. Naber, "Electricity generation from biomass via the HTU process", DGMK Conference "Energetische und stoffliche Nutzung von Reststoffen und nachwachsenden Rohstoffen", Velen (1994). DGMK Tagungsbericht 9401 (ISBN 3-928164-70-8)

J.E. Naber and F. Goudriaan, "Further development and commercialisation of the Shell Hydrothermal Upgrading process for the liquefaction of biomass", Altener seminar "Energy from waste and biofuels", Amsterdam, RAI, 26 May 1997.



the Peleato file...

By Marina Peleato, University of Zaragoza, Spain

As part of PyNE's continued mission to increase awareness of **Pyrolysis activities** throughout Europe, funds have been set aside to pay for young researchers from PyNE organisations, to visit other laboratories to gain experience and exchange information and ideas. Visit reports are filed with Tony Bridgwater and will be published in this and future newsletters.

For one of the research exchange visits supported by PyNE, Marina Peleato, a collaborator of Professor Jesus Arauzo at the University of Zaragoza Spain, visited the **Unité de Catalyse et Chimie des Matériaux Divisés at UCL Belgium**, supervised by Dr Rosanna Maqqi.

The work of Marina at Zaragoza University involves the analysis and characterisation of liquids from gasification and pyrolysis of biomass. The samples come from gasification plants with a capacity of 100-200 kg/h and a bench scale pyrolysis unit. These liquids are not oil in the conventional sense but have a high water content. This introduces difficulties in their analysis and characterisation. The objective of the visit was to learn about the methodology of analysis for the characterisation of bio-oils as developed by the group led by Professor Delmon and Dr Maggi in order to apply this methodology to those samples.

Two samples – one from pyrolysis and one from gasification of straw pellets were studied. The following analyses were made:

- Density.
- Viscosity.
- Water content by Karl Fischer titration
- Solubility in different solvents
- Chemical analysis: The bio-oils were fractionated by adsorption chromatography technique with sequential elution by different solvents with increasing polarity. The individual fractions were analysed by GC-MS.

Results

Both oils had a high water content (about 83%), a density equal to 1g.cm³ and a low viscosity (<10cp) explained by the high water content. As a general result, the chemical composition of the volatile compounds in both samples were found to be very polar and oxygenated products as most of the compounds are elued in fractions 4 (Diethyl ether) and 5 (methanol).

The main products in the sample from the pyrolysis experiments were:

- acetic acid.
- 1-hydroxy-2-propanone.
- 1-hydroxy-2-butanone.
- 2-furanmethanol.
- 2-furancarboxaldehyde.
- Others compound identified included butyrolactone, crotonolactone, guaiacol, pyrocatechol and 2,6-dimetoxyphenol.

On the other hand, the main products in the sample from the gasification experiments were:

- acetic acid.
- phenol.
- cresol.
- other compounds registered were phenolic derivatives, butyrolactone, 1-hydroxy-2propanone and propanoic acid.

Conclusions

Different bio-oils contain different products that require specific analysis. The selection of appropriate methodologies for each bio-oil require more intensive studies. Continued collaboration between analytical centres in Europe will aid progress in this area.

"Continued collaboration between analytical centres in Europe will aid progress in this area."



Loukas Gabriel visits...

By Loukas Gabriel, CRES, Greece

In the framework of the PyNE personnel exchange scheme I visited the **Energy Research Group at Aston University in Birmingham, UK.** The scope of my visit was to be informed about the operation of the biomass pyrolysis reactors that have been developed by the Group, participate in experimental runs on these reactors and observe the procedures that are followed for the characterisation of the bio-oil.

Aston University has built two bubbling fluidised bed reactors for the fast pyrolysis of biomass. The first reactor operates at a feeding rate of 1 kg biomass/h and is equipped with a quench column and an electrostatic precipitator (EP) for efficient bio-oil recovery. A series of experimental runs were executed in this reactor in order to test the performance of the new

"In conclusion, it was found that the equipment at Aston University is very convenient and easy to use." equipment as well as the yields from different biomass feedstocks. The results from these runs are still being analysed.

The second reactor

operates at 0.1 kg biomass/h feeding rate. Its downstream train is currently equipped with two glass condensers – one cooled by dry ice and the other by ice, an EP and a cotton wool trap. It has three product collection points, one from each condenser and one from the EP. This reactor is used for tests of co-feeding biomass and catalyst for pyrolysis vapour upgrading studies as well as small scale screening tests.

During my visit I had the opportunity to participate in experimental runs of the larger fluid bed for the commissioning of the recently installed EP. There were problems of arcing between the two electrodes during these tests



but after some modifications the EP worked satisfactorily, removing the majority of escaping aerosols and producing a very clear gas. The whole experimental set up is very easy to handle, it quickly reaches operating conditions and is proven to be reliable and simple in operation. One problem is that it requires a lot of manual readings and that there is no continuous gas sampling from the process. However, the ease of operation makes this set up ideal for testing various materials.

A couple of runs were performed in the small FB as well. The scope of the runs was to test the product quality by using specific proportion of catalyst along with the biomass feed. Bio-oil and gas samples from the process were collected. The small size of the equipment and the ability to achieve well controlled operating conditions, can result in very accurate mass balances and give useful conclusions about the reaction kinetics of the process.

Finally, I operated the equipment that determines the water content in the bio-oil samples. This was a typical Karl-Fischer titration instrument made by Mitsubishi. Samples were diluted in methanol with a known water content and were then injected in the instrument, which directly gave the water content of the solution.

I also learned about the methods used for the analysis of bio-oil samples by HPLC. The water soluble substances, like sugars, organic acids, etc., that are contained in bio-oil are determined by this method.

In conclusion, it was found that the equipment at Aston University is very convenient and easy to use. This makes it ideal for various tests since the reactors can be brought to operating conditions in a very short time. Moreover the analytical equipment serves as a valuable tool for the evaluation of both biomass feedstock and final products.

Loukas Gabriel in the Aston University Pyrolysis Laboratory.



PKA was founded in 1983 as an engineering company for the development and marketing of pyrolysis. The principle of pyrolysis has been used by mankind for millenia to produce charcoal. In the industrial age, pyrolysis was used to make coke from coal, and that technology was very well developed.

> PKA have applied the principle to effectively solve a waste management problem and recovery a valuable energy product.

> Extensive experience has been obtained with a variety of feed materials including pre-processing and agglomeration of raw materials and residues; sewage sludge drying; pyrolysis and gasification of coal; processing of waste, residues and biological matter; gas processing,

cleaning and utilisation. Of particular relevance is the experience gained with old tyres, car shredder residues (auto fluff), packaging materials and hazardous waste.

Description of the technology

The basic concept consists of three steps - waste preparation, pyrolysis and clean gas production:

- Wastes and residues are, as a general rule, pre-processed in two stages by grinding and metal separation, then dried if the moisture content is too high.
- The material is pyrolysed at a temperature of 500°C to 550°C giving two products pyrolysis gas which is thermally cracked and char which is gasified with the product gas being combined with cracked pyrolysis gas.
- The gas is finally scrubbed to provide a clean fuel gas for heat and power applications.

The process is depicted in Figure 1.

Gas product

The pyrolysis gas is drawn through a hot zone in the gas cracking unit at over 1000°C with a retention time of up to 2 seconds. This thermally destroys organic contaminants including tars and oils, and also results in a more consistent gas quality.

Char product

The pyrolysis residue (char) is prepared by grinding and metal separation for further utilisation in a gasifier. The prepared char is fed into the gasification reactor using oxygen enriched air as the gasifying agent at 93% 02 at a temperature of about 1500°C. The product gas is mixed with cracked pyrolysis gas and fed to the gas scrubbing unit to remove traces of dust and tar. The mineral components in the char are melted at the temperature of gasification and become a fine grain glass granule.

Gas cleaning

The cracked gas is quenched and wet scrubbing where inorganic acid pollutants are washed out. The gas is then dried and further processed to remove any remaining organic pollutants as well as mercury and hydrogen sulphide. The cleaned gas has a heating value of approximately 4.000 kJ/Nm3. It may be immediately exported to external consumers or converted on site into electricity and heat.

In this system, waste can be efficiently processed and a clean gas can be produced for use in an existing power plant. A modular system is provided to enhance this basic concept according to specific local requirements, for example to heat a furnace or generate electricity. Modules can be arranged in multiples and run in parallel, which permits the flexible scaling up of a system.

Facilities and applications

PKA operates a research plant with approximately 400 kg/h throughput. A unit is currently under construction for 24.000 t/a of household waste at Aalen. The energy produced is directed to an electricity generating plant and heat is delivered to a nearby hospital and school.



The Freibera Research Plant



Figure 1. PKA Pyrolysis Process Flowsheet



UmwelttechnikGmbH & Co. KG Heinrich-Rieger-Strasse 5 D-73430 Aalen Germany Tel 07361/57230

Fuel Testing Methods for Bio-oil By Anja Oasmaa, VTT Energy, Finland

Background

VTT, the Technical Research Centre of Finland, has over 20 years of experience in analysis and characterisation of fuels (see PyNE newsletter 3 for profile). This experience of standard fuel oil analyses developed for petroleum-based fuels has recently been applied to several different fast pyrolysis liquids. Fuel oil analysis methods unsuitable for pyrolysis liquids have been identified. In addition, research on sampling, homogeneity, stability, miscibility and corrosivity have been carried out. Recommendations for sampling, and sample size and minor modifications in standard methods have been described (1). Further development will be carried out with different types of fast pyrolysis liquid and by using new methods.



Results after homogenisation (1-2h) of the barrel * Acetone insolubles

Homogenisation and sampling

The homogeneity of the liquids is the most critical factor in an accurate analysis. Attention must be paid to the mixing and sampling of the liquid. The methods depend on the type and size of the pyrolysis liquid container as shown in Figure 1. The homogeneity of the liquid after mixing can be verified, for example by sampling from different depths and by analysing the moisture and solid content of the different layers. Some representative results are shown in Figure 1. Heating of the liquid should be avoided to prevent evaporation of volatiles and/or viscosity increase due to the instability of the liquid. Handling, storage, and pumping may all affect the properties of the pyrolysis liquid in different ways.

Standard fuel oil methods

In general, most of the standard methods can be used as such but the accuracy of the analyses can be improved by minor modifications. The presence of air bubbles may affect many analyses such as viscosity, density, or flash point determinations. Sample preheating (pour point) and prefiltration (viscosity) recommended in the standard should be avoided when possible. The former may cause changes in the composition and structure of the pyrolysis liquid and the latter may remove part of organic material with particles. The size of the sample should be determined on the basis of the homogeneity and the water content of the liquid. The criteria for fuel oil quality may vary depending on the projected use of the liquid. For determining the fuel oil quality of the pyrolysis liquid, suggested methods for analysis with comments on modifications are listed in Table 1. A quick stability test is included.

Table 1. Basic fuel oil properties for Pyrolysis liquids.

Analysis	Method	Size of the sample req'd ¹
Water, wt%	ASTM D 1744 ²	1 g
рН	pH meter	50 ml
Solids, wt%	Ethanol insolubles ³	3 g
Ash, wt%	EN 7 ⁴	40 ml
Conradson carbon, wt%	ASTM D 1894	2-4 g
Heating value, MJ/kg		
calorimetric (HHV)	DIN 51900	1 ml
effective (LHV)		
Carbon, hydrogen, nitrogen, wt%	ASTM D 5291-92	1 ml
Density (15 °C), kg/dm3	ASTM D 4052	4 ml
Viscosity, cSt	ASTM D 445⁵	80 ml
Pour point, °C	ASTM D 97 ⁶	80 ml
Flash point, °C	ASTM D 937	150 ml
Stability	80 °C 24 hours ⁸	200 ml
Sulphur and chlorine, wt%	Capillary electrophoresis ⁹	2-10 ml
Na, K, Ca, Mg, wt%	AAS ¹⁰	50 ml
Metals, wt%	ICP, AAS ¹⁰	50 ml

NOTES

- Minimum amount of pyrolysis liquid needed for two determinations.
 Karl-Fischer titration. Chloroform-methanol (1:3) solvent. HYDRANAL-K reagents (Composite 5K and Working Medium K) in case of a fading titration end-point. 50 ml solvent for two determinations. Sample size about 0.25 g (water content >20 wt%). Stabilisation
- time 30 s.
 3 Millipore filtration system, 0.1 µm filter, sample size 1-3g, sample:
 solvent = 1:100.
- 4 Controlled evaporation of water to avoid foaming.
- 5 Cannon-Fenske viscometer tubes at room temperature and for nontransparent liquids, Ubbelohde tubes may be used for transparent liquids. No prefiltration of the sample if visually homogenous. Eliminate air bubbles before sampling. Equilibration time 30 minutes at 20°C and 50°C, 20 minutes at 80°C.
- No preheating of the sample.Elimination of air bubbles before sampling.
- 8 90 ml pyrolysis liquid in 100 ml tight glass bottles, heating in an oven. Measurement of increase in viscosity and water. Viscosity determination at 50°C according to ASTM D 445.
- 9 Sample pretreatment by combustion according to ASTM D 4208
- 10 Wet combustion as a pretreatment method.

Reference

Oasmaa, A., Leppämäki, E., Koponen, P., Levander, J. and Tapola, E. Physical Characterization of Biomass-Based Pyrolysis Liquids. Application of Standard Fuel Oil Analyses. VTT Publications 306. 46 p. + app. 30 p. Espoo, 1997.

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Dynamotive Technologies Biotherm[™] Fast Pyrolysis

By Raymond McAllister, DynaMotive, Canada

DynaMotive Technologies Corporation is currently scaling up and commercialising its Biomass Refinery family of clean energy products and technologies.

Pictured here at the bio-oil plant are Dr. Joe Zhou, senior engineer for BioLime® and bio-oil (left) with Product Director Bert Put (right).



refinery is the BioTherm[™] process - a fluidised bed fast pyrolyser based on a previous design by Resource Transforms International Ltd. (RTI). The process maximises bio-oil output from agriwaste, woodwaste or the lignocellulosic portion of steam processed municipal solid waste (1).

The core of the

It has been demonstrated at RTI at 15 kg/hr capacity on a variety of feedstocks including sawdust. DynaMotive is now optimising the performance of this new half tonne per day unit (see photo) which is located next to its 25 tonne per day BioLime® plant (see PyNE news issue 3). A 25 tonne per day capacity pyrolysis unit is currently being designed.

The biomass feed is first sized and dried to 15% or less moisture. The heat required to operate the pyrolyser can come from by-products such as pyrolysis gas, char or other Biomass Refinery products. Pyrolysis gases and mists are separated from the solids to form a gaseous product called BioSol[™] (2).

This can be utilised as fuel in systems that are close coupled to the pyrolyser or condensed to make bio-oil. Char and ash which are separated from the BioSol stream can be used for heat recovery or production of value added products such as activated carbon. Pyrolysis off-gas is utilised via a recycle blower as fluidising gas to the pyrolyser or can be incinerated to produce heat input to the pyrolyser. bio-oil can be used as a fuel or upgraded to a variety of chemical products (3). The pyrolyser is currently operating on mixed sawdust feedstock. In future tests, the plant will be operated on feedstock produced in DynaMotive's high speed biomass pulveriser called DynaMill[™].

Initially the bio-oil output will be used to produce a variety of products including BioLime® (4), (see PyNE news 3 for details) and other value added chemicals. DynaMotive recently formed a business alliance with Lockheed Martin Idaho Technologies Co. which operates the United States Department of Energy Idaho National Engineering and Environmental Laboratory (INEEL). The purpose of this alliance is to demonstrate BioLime® air emission control technology at the 7 MWe coal fired power plant operated by INEEL. This will be the first commercial demonstration of BioLime®.

References

- 1) Radlein, D, Piskorz, J and Majerski, P, patents pending, RTI, Waterloo, Canada
- 2) Radlein, D, Piskorz, J and Majerski, P, patents pending, RTI, Waterloo, Canada
- 3) Oehr, K, Skelton E and Barrass G patents pending, Dynamotive, Vancouver, Canada.
- Oehr, K et al. patents pending and issued, Dynamotive, Vancouver, Canada

Pictured here at the bio-oil plan

Pyrolysis News from Canada

By Ed Hogan, Natural Resources Canada, Canada

Recent results from the **Ensyn** RTP[™] 15 ton/day unit at the **ENEL** facility in Bastardo, Italy indicate that the pyrolysis tests have been successful. The system has run continuously for over 80 hours at a feed rate of approximately 500 kg/hour, using 35,000 kg of hardwood feedstock to date. The bio-oil quality has been found to be very good in terms of viscosity, moisture content and consistency.

A five litre per hour continuous unit for the production of stable mixtures of pyrolysis oil and diesel fuel has been built and successfully commissioned at the **CANMET** research facilities in Ottawa. Samples of mixtures having concentrations of 10%, 20% and 30% bio-oil in diesel have been prepared and shipped to VTT– Energy for testing. Analytical, corrosion and preliminary combustion tests will be performed by VTT to evaluate the potential use of this mixture in conventional heat and power systems.

> **Resource Transforms International** will be co-ordinating a recently initiated project to measure the biodegradability of pyrolysis oils. Tests using the conventional CEC L-33-T-82 method have not been successful because pyrolysis oil cannot be mixed with the diesel standard. The current tests will determine whether respirometry could be used a method of measuring biodegradability.

The Manitowoc Public Utilities (MPU), Manitowoc, Wisconsin USA has recently released a report on the successful utilisation at their power facility of pyrolysis oil produced from the Ensyn RTP[™] unit at the Red Arrow Products Company facility. The report states that only simple cost effective modifications had to be made to a Wicks 20 MWe coal fired boiler in order to permit the co-firing of bio-oil at a level of 5% or 1 MWe (heat input basis) for the commercial production of power.

Conclusions from the report were:-

- 1. the combustion of the bio-oil was clean and efficient with no adverse changes in measured emissions levels,
- 2. bio-oil firing was routine without any inconvenience to the power plant operation,
- 3. no additional maintenance activities were required when operating with bio-oil,
- 4. no changes to ash handling were required,
- 5. post maintenance revealed no observed detrimental effect to the boiler or peripheral equipment.

stop press...

Continuation of the PyNE Network has just been approved by the European Commission. In addition, this will be merged with the IEA Bioenergy Pyrolysis Activity from the start of 1998 to provide the best integration of the pyrolysis activities throughout Europe and North America.

The European Market for Bio-oil use in Internal Combustion Engines

By Steve Burnett, Impax Capital Corporation Ltd. UK

Very few would argue that biomass, in its many forms, exists in abundance throughout Europe, or that it has tremendous potential as a fuel resource for the future. What is much more difficult is to measure the real commercial potential for biomass-to-energy project development.

As part of a contract awarded to Ormrod Diesels from the European Union (APAS/RENA-CT94-0070), Impax Capital has been co-ordinating an international effort to investigate the market potential for dual fuelled diesel engines using bio-oil derived from the flash pyrolysis of biomass. The market research has been looking in detail at the commercial potential in 5 countries: Greece, Italy, Spain, Austria and the UK, which in turn has informed a generalised view of the EU market overall.

Such an exercise can only begin to measure the true potential for fast pyrolysis, since the process can produce other commercial products besides bio-oil. For pyrolysis/engine systems, there are also questions of plant size, configuration and system location (embedded generation or grid connection) which, while emphasing their flexibility in application, also make the measure of future installed capacity very difficult.

Because fast pyrolysis/engine systems cannot yet compete directly with traditional power systems in terms of cost-efficiency, they rely fundamentally on one of two pre-conditions; the availability of nil or negligible cost fuel, or the presence of artificial market supports to, for instance, subsidise capital costs or boost power revenues. Practically all European governments now have such support mechanisms, which leaves fuel availability and cost as the main determinant.

"The market research has been looking in detail at the commercial potential in 5 countries: Greece, Italy, Spain, Austria and the UK." Our assessment therefore has started by measuring the availability of biomass fuels, in particular forestry residues and energy crops. The former is generally available in all countries, but tends to be exploited as a fuel source mostly where there is an abundance of forests and/or where the use of wood for home heating survives as a traditional practice. These countries, such as Austria, Sweden, Finland, would be highly accessible to the promoters of fast pyrolysis systems, although the orientation would likely favour heat production rather than electricity, in parallel with existing activities.

Systems utilising energy crops as fuel will be more difficult to establish since the fuel supply system (crop husbandry, harvesting and chipping) would need to be developed in parallel with the energy plant. The availability of arable farmland for this purpose is not in question, but the farmers need to be compensated at rates competitive with other cash crops, and this will increase the economic burden on the developer.

Each of the five countries analysed has a unique profile of biomass resources, as well as legislative, institutional and economic factors which influence commercial potential:

- Spain, probably will experience slow capacity growth until the power supply market becomes more accessible to independent producers, but there is a strong tradition of utilising biomass fuel and an abundance of resources.
- The UK has very strong potential, but is starting from a very low level of experience with forest residues and energy crops. However the energy markets are the most open in Europe.
- In Greece, agro-industrial residues (cotton wastes, olive wastes etc.) are the greatest resource, with some forestry residues. Potential therefore will be limited until fast pyrolysis can be demonstrated to handle a wider mix of fuels.

- In Italy, official support is currently very strong, but the longer term view remains unclear. This may well be the earliest market to develop, and eventually the strongest over time.
- In Austria, biomass already contributes 13% of the primary energy requirement, mainly domestic heating. This well established biomass/heat infrastructure is highly accessible, but electricity will be much more difficult given the bias in government support for heat.

An overall view of the opportunities is shown in the table. The aggregate view of European market potential is strictly a guidance figure, since adding up the wide variety of individual national experiences dilutes its meaningfulness.

The overriding conclusion is that fast pyrolysis/engine systems can serve a limited but important niche in the European renewable energy market. Fast pyrolysis is likely to comprise only one of several commercially viable technologies for the exploitation of biomass over the next 20 years. Also, this analysis is of a specific, defined opportunity in energy generation which probably underestimates the broader potential of both the biomass industry in each country and the ability of the technology to serve other industries.

Country 2 Spain 7 UK 1 Greece 7	2005 : .4	2010 22 51	2015 59	2020 103
Spain 7 UK 1 Greece 7	.4	22	59	103
UK 1 Greece 7	.4	51		
Greece 7		51	102	159
		15	39	75
Italy 2	:0	63	117	179
Austria 1	.0 4	43	67	114
EU-15 1	.45	485	960	1575



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PyNE visit to Chemviron Carbon



By Cordner Peacocke, Aston University, UK.

As part of the PyNE meeting in Hamburg in June 1997, a visit to Chemviron Carbon, Bodenfelde was arranged.

Chemviron Carbon produced charcoal and wood derived chemicals. 70-80,000 t/y of predominantly beech wood are carbonised in retorts to make approximately 23,000 t/y of charcoal, for use mostly in the domestic market as a barbecue fuel. The beech wood used in the process is transported from the local area, up to 100 km from Bodenfelde. The wood is dried at 150°C for 30 hours in a rotary drier prior to carbonisation at 530-550°C for 15 hours. The gases and vapours are cooled and quenched. Very pure acetic acid is recovered in a 19 stage process for an annual market of 500t of 100% acetic acid for use in the electronics industry. Smoke flavours are also produced. Other chemicals can recovered such as propionic acid but these are not currently economic.

The plant tour covered all processing stages from wood reception, through drying, feeding, pyrolysis and product recovery as charcoal briquettes and chemicals. The acetic acid purification plant was also visited as well as the analytical facilities. The problems of analysing the complex chemicals found in pyrolysis liquids was discussed with several PyNE members. The production of acetic acid for a niche market demonstrated that applications for chemicals from pyrolysis liquids can be found and exploited. Several of the PyNE members have subsequently maintained contacts with Chemviron Carbon, looking at liquids analysis and applications for other chemicals in the pyrolysis liquids.

For further information please contact:-

Mr K Schunda Chemviron Carbon Uslarer Strasse 30 Bodenfelde D-37194 Germany



Aerial View of the Chemviron Carbon Plant.

Complementary Publications

EUROPE

CREST News (quarterly newsletter)

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European Media Marketing Ltd. 6th Floor, 22-26 Albert Embankment London, SE1 7TJ, UK Tel: +44 171 735 8880 Fax: +44 171 793 8007 Email: journal@emml.demon.co.uk

Renewable Energy Journal (six-monthly)

The Franklin Company Consultants Ltd. 192, Franklin Road Birmingham, B30 2HE, UK Tel: +44 121 459 4826 Fax: +44 121 459 8206

Greenhouse Issues

IEA Greenhouse Gas Programme CRE Ltd. Stoke Orchard Cheltenham Glos. GL52 4RZ, UK Tel: +44 1242 680753 Fax: +44 1242 680758 Email: andrea@ieagreen.demon.co.uk

Synergy

European Commission 200 Rue de la Loi B-1049 Brussels Unit A4 – 226 Avenue de Tervuren B-1150 Brussels, BELGIUM Tel: +32 2 299 1111 Fax: +32 2 295 0150

OPET News (every six weeks)

OPET Coordinating Unit 13b, Avenue de tervuren B – 1040 Brussels, BELGIUM Tel: +32 2 743 8930 Fax: +32 2 743 8931 Email: opet_cu@ecotec.com

Fedarene

European Federation of Regional Energy and Environment Agencies 11 rue du Beau – Site – B 1000 Brussels, BELGIUM Tel: +32 2 646 8210 Fax: +32 2 646 8975 Email: fedarene@inforboard.be

Sustainable Energy News (four issues

per year) c/o InforSE P.0. Box 2059 DK - 1013 Copenhagen K, DENMARK Tel: +45 33.12.13.07 Fax: +45 33.12.13.08 email: inforse@inforse.dk http://www.inforse.dk/

APAS – RENA RESMED Network News

Dr Platon Baltas C.R.E.S. 19th km Marathonos Ave. GR – 190 09, Pikermi GREECE Tel: +30 1 603 9900 Fax: +30 1 603 9905 Email: pbaltas@leon.nrcps.ariadne-t.gr

THAILAND

RERIC News

Regional Energy Resources Information Centre Asian Institute of Technology G.P.O. Box 4, Klong Luang Pathumthani 12120, THAILAND Tel: +66 2 52 45 866 Fax: +66 2 52 45 870 or 51 62 126 Email: enreric@ait.ac.th http://www.clair.ait.ac.th/centers/reric/

Wood Energy News

Regional Wood Energy Development Programme in Asia FAO Regional Office Maliwan Mansion, Phra Atit Road Bangkok 10200, THAILAND Tel: +66 2 280.2760 Fax: +66 2 280.0760 Email: rwedp@field.fao.org

KENYA

Regional Energy News

 The Forest Action Network

 P.O. Box 21428

 Nairobi, KENYA

 Tel:
 +254 2 718 398

 Fax:
 +254 2 718 398

 Email:
 fan@arcc.or.ke

UNITED STATES

Biologue (Quarterly magazine)

National BioEnergy Industries Association (NBIA) 122 C Street, N.W., 4th Floor Washington, D.C. 20001-2109, USA Tel: +1 202 383 2540 Fax: ++ 202 383 2670

SERBEP Update (monthly newsletter)

Philip Badger, Manager Tel: +1 205 386 3086 Email: pcbadger@tva.gov

Energy Crops Forum (Three times a year)

Anne Ehrenshaft, Editor Biofuels Feedstock Development Program Oak Ridge National Laboratory P.O. Box 2008 Oak Ridge, TN 378316352,USA Tel: +1 615 576 5132 Fax: +1 615 576 8143 Email: are@ornl.gov

Calls for **Proposals**

FAIR

Fair programme a	reas, 3, 4, 5
Closing Date:	15.09.97
Contact: Fax:	+32 2 296 4322
OJ Reference:	15.06.1997

The publication of the 6th call for proposals originally scheduled for 17.6.1997, is expected for 15.10.1997 16.01.98 Closing Date: Contact: Fax: +32 2 296 4322 OJ Reference: 15.10.1997

Co-operative research projects for SME's

Closing Date:	08.04.98
Contact: Fax:	+32 2 296 4322
OJ Reference:	17.12.1996/C381

JOULE

Demon	stratior
Closina	Date:

Contact: Fax:

OJ Reference:

17.12.97 +32 2 295 0656 (DGXII) 15.12.1994/C357

TRAINING & MOBILITY OF RESEARCHERS (TMR)

Research Training Grants

Closing Date: 15.12.97 Estimated date of selection: 15.05.98 Contact: Email: tmr-grants@dg12.cec.be OJ Reference: 15.09.1997

Euroconferences, summer schools and

practical training courses Closing Date: 31.03.98 Estimated date of selection: 30.09.98 Contact: Email: tmr-info@dq12.cec.be OJ Reference: 15.12.1997

THERMIE & ALTENER

There are no calls for proposals for THERMIE or ALTENER programmes.

Diary of Events

1997 International Conference on Use of **Biofuels for Transportation**

Venue:	Stockholm, Sweden
Date:	29 September – 1 October 1997
Contact:	Miss Eva Stenberg, Hamngatan 19, S-831 34, Ostersund, Stockholm, Sweden
Tel:	+46 63 10 88 17
Fax:	+46 63 10 78 40
Email:	ingrid.andersson@fr.se

World Power and Energy '97

Venue:	Birmingham, UK
Date:	7-9 October 1997
Contact:	Allan Gibbs, Nexus Media Ltd
Tel:	+44 1322 600070
Fax:	+44 1322 667633

The Asia-Pacific Initiative – For Renewable **Energy & Energy Efficiency**

Venue:	Jakarta Convention Centre – Indonesia
Date:	14-16 October 1997
Contact:	ADA Ltd, 5/F 3 Wood Road, Wanchai, Hong Kong
Fax:	+852 2574 1997
Email:	altdev@hk.super.net
www:	http://www.hk.super.net/~altdev/

Third Japan-EU Joint Workshop on The Frontiers of Catalytic Science & Technology for Energy, Environment and Risks Prevention

Venue:	Tsukuba, Japan
Date:	25-28 November 1997
Contact:	Dr Akio Nishijima, National Institute of Materials and Chemical Research, 1-1, Higashi, Tsukuba, Ibaraki 305, Japan.
Tel:	+81 298 54 4532
Fax:	+81 298 54 4534
Email:	saito-ik@nire.go.jp

7th International Symposium – Scientific **Bases for the Preparation of Heterogeneous** Catalysts

Venue:	Louvain-la-Neuve, Belgium
Date:	1-4 September 1998
Contact:	Dr G Poncelet or Dr R Maggi
Tel:	+32 10 473596/473652
Fax:	+32 10 473649
Email:	poncelet@cata.ucl.ac.be OR Maggi@cata.ucl.ac.be

World Renewable Energy Congress

/enue:	Florence, Italy
Date:	20-25 September 1998
Contact:	Prof. A A M Sayigh, World Renewable Energy Network, 147 Hilmanton, Lower Earley, Reading, RG6 4HN, UK
Tel:	+44 (0)118 961 1364
Fax:	+44 (0)118 961 1365

Progress in Thermochemical Biomass Conversion

/enue:	Bavaria, Germany
Date:	May 2000
Contact:	A V Bridgwater, Aston University, Birmingham, B4 7ET, UK.
Tel:	+44 (0)121 359 3611
ax:	+44 (0)121 359 6814
mail:	a.v.bridgwater@aston.ac.uk

Items for inclusion in the diary can be submitted directly via the Internet on http://www.ceac.aston.ac.uk/PyNE/Diary/diarysu b.html or sent to the diary co-ordinator, Karsten Pedersen in Denmark, or Claire Humphreys at Aston University.

Please contact your country representative for further information.

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For further details or offers to contribute, please contact Claire Humphreys (see inside front cover for details). Any opinions published are those of the contributors and do not reflect any policies of the EC or other organisations. EOE