Char Char Char: A Dance with Fire

The following is the content of a PowerPoint presentation delivered at Sturt Woodfire 08. As the following contains only the text and images from the slides used this provides only an outline of the talk given. As the topic created significant interest I have decided to produce an article in the near future that is likely to be published in Ceramics Technical covering the subject in more detail. If you have further questions please contact by email: gary.hill@latrobe.edu.au

A great deal of research has been conducted into combustion and more information on the subject can be found in a variety of publications. A good starting point is the following two web sites:

http://www.wfra.com.au/ 20551.pdf

http://www.fpl.fs.fed.us/documents/fplr/fplr2136.pdf

Char Char Char

A Dance with Fire

Myth or fact?

- The direct burning of wood provides heat within the kiln
- Light wood, such as pine, is needed to provide a flame long enough to reach wares in the rear of the kiln
- If a kiln stalls add more fuel and air to increase combustion

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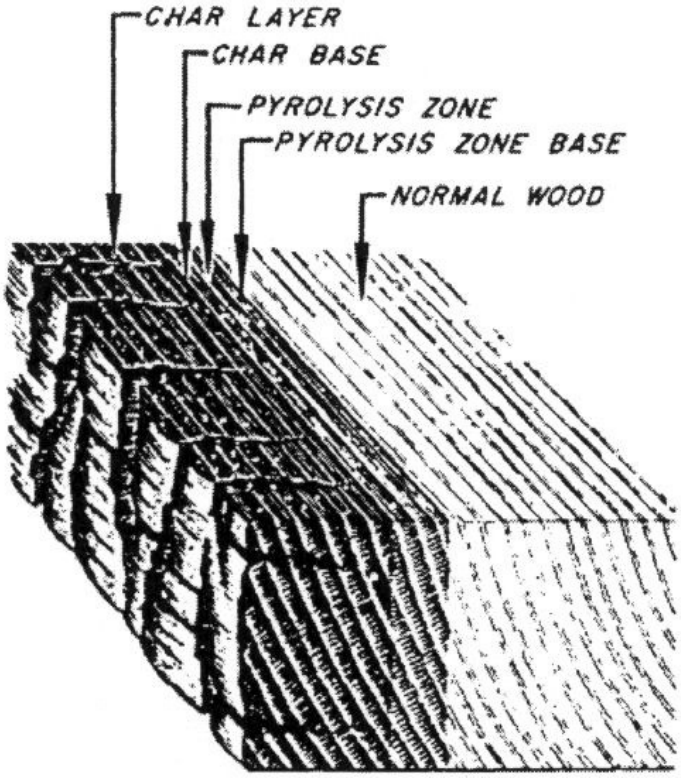
The 3 requirements for combustion

- Fuel
- Air
- An ignition source

Wood degradation zones



Degradation zones in a wood section

Schaffer. E. L. 1967

Pyrolysis Zone Base

- 95°C - 200°C
- Water is given off and wood will become charred

Pyrolysis Zone

- 200°C-280°C
- Acetic acids, formic acid, glyoxal as well as water vapour are given off. Ignition, though difficult, is possible.

Char Base

- 280^{o}C - 500^{o}C
- Combustible gases such as carbon monoxide, methane, formic and acetic acids, hydrogen, formaldehyde and methanal, which are diluted with carbon dioxide, are given off. The residue of this process is black fibrous char. If the temperature is held below 500oC little flame is observed and a thick layer of char builds up.

Char Layer

- 500^{o}C and over
- Remains are primarily charcoal which glows and is consumed without flame but provides significant heat

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Factors affecting the combustion of wood

- Level of radiant heat exposure
- Moisture content
- Wood dimensions
- Density and porosity of wood
- Species of wood
- Formation of char

Heat exposure

- The processes of pyrolysis of wood are dependant on the temperature the wood is exposed to
- The temperatures at which these processes occur are altered by association with oxygen

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Heating

- Rapid heating through the range of active pyrolysis produces less charcoal and more combustible gasses than slow heating
- In very rapid heating macromolecules can be torn into volatile fragments rather than orderly crystalline structures

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Why does the temperature drop when we stoke a kiln?

- The chemical decomposition of wood is initially an endothermic reaction and, at this stage, is a net user of energy (heat) rather than a contributor
- The reduction of available oxygen due to the introduction of excessive fuel further exasperates this unless the products of pyrolysis are retained in the kiln long enough to contribute to combustion

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Moisture content

- A moisture content of less than 10-20% has little effect on decomposition rates
- At high temperatures (over 500oC) water vapour is subject to secondary pyrolysis and is highly combustible (Water vapour and carbon dioxide react with carbon to form carbon monoxide, hydrogen and formaldehyde)

Dimensions

- Thickness of the wood effects decomposition, but there is a catch. Given equal density thinner sections decompose quicker than thick sections BUT once the section is over approximately 6.5mm thick little difference in decomposition rates are observed.
- Thin wood has a greater surface area per weight unit than thick wood

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Heat capacity

- The more mass available to absorb heat, due either to density or physical proportion, the slower the decomposition

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Porosity

- A study conducted by Wright and Hayward showed that the rate of decomposition of wood cut across the grain was approximately twice that of wood cut along the grain.
- High porosity assists in the transfer of the products of pyrolysis to the surface

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Porosity and thermal conductivity

- Thermal conductivity is inversely proportional to void volume, lower void volume equals higher heat transfer
- large void volumes increases decomposition due to increased localised overheating

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Density

- The rate of mass loss is directly proportional to the density of the wood, the higher the density the higher the mass loss
- Char formation in dense woods is lower allowing higher heat penetration rates
- Less dense woods have wider fissures in the char layer allowing faster heat penetration

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Australian timber densities

Blackbutt	939 kg/m3
Blue gum	939 kg/m3
Brush box	819 kg/m3
Cypress pine	666 kg/m3
Jarrah	848 kg/m3
Radiata pine	526 kg/m3
Spotted gum	901 kg/m3
Victorian ash	659 kg/m3

Species

- Variations in the combustion of species is not only dependent on the density and porosity of that species but also its chemistry

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Formation of char

- The layer of char on the surface of burning wood acts as an insulator. This reduces the temperature deeper in the wood reducing decomposition and the emission of flammable gasses

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Rate of charring

- The rate of charring is a complex issue depending on the interaction between pyrolysis and the generation of heat, both of which are a function of all the factors previously mentioned.

Charing rates mm/min

Light dry wood	0.8
Medium density softwood	0.6
Softwoods	0.61-0.84
Hardwoods	<0.53
Heavy, moist wood	0.4
Timber in general	0.6-1

It all means?

- While we all can, and do, fire our kilns successfully a basic understanding of the factors which control combustion can not only aid us in obtaining the results we desire but help us to achieve this with the least impact on the environment in which we live

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Finally

- The art of producing ceramics, woodfired or not, is very dependant on process and, while I subscribe to the principle of ‘mindless work’ as promoted by Soetsu Yanagi and yesterday so wonderfully by Neil Hoffman, the ability to engage this principle is ultimately dependant on a deep understanding not only of aesthetics and ceramic process but the underlying principles of the firing process as well

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