Thoughts on Mixing Pyrolysis Gas and Secondary Air In the TLUD Cooking Stove

The TLUD cooking stove is a gas stove that makes its own gas by pyrolyzing solid biomass fuel.

The created gas rises to a burner where it is mixed with air (called secondary air) and ignited to combust its flammable components.

To attain efficient burning of the pyrolysis gas, a main interest is the efficient mixing of the pyrolysis gas with the secondary air. Efficient and rapid mixing leads to shorter, hotter, and more efficient flames.

This presentation is a discussion of the mixing and burning of gasses in the TLUD biomass cook stove, with special attention to the very effective Venturi mixing technique.

Basic principles important for mixing gasses in a TLUD:

1. Contact area between the gasses
2. The depth the gasses must penetrate into each other
3. The pressure difference (gradient) between the gas and air
4. Permeability of the gasses
5. Movements and directions of the gasses
6. Temperature of the gasses
7. Contact time

The above principles are important considerations for the following mixing techniques.

Mixing techniques in the TLUD type wood stove

- Turbulence mixing
  - Static mixer/moving gas
  - Stirring/moving mixer
- Diffusion mixing
- Concentrator mixing
- Air stream mixing
- Pressure gradient mixing

Turbulence Mixing

Physically disrupts the flow of the gasses with vortexes and eddies created as the moving gas passes a stationary turbulator device.

Stirring

Uses either the energy of the flowing gasses (like the flow spinning a propeller), or a powered machine like a blender to mix the gasses.

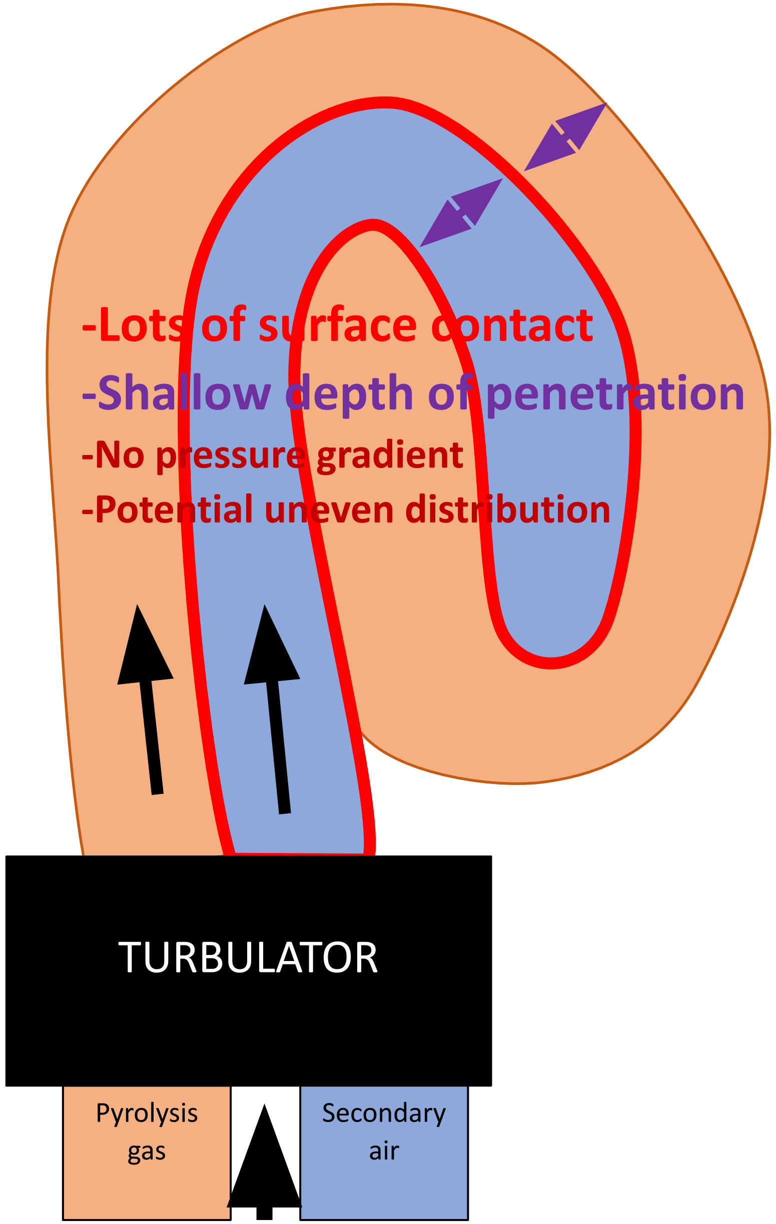
Turbulence mixing

Strengths:

- Large surface contact
- Shallow depth of penetration

Weaknesses:

- No pressure gradient
- Large potential for uneven distribution
- Takes time and space to mix



Diffusion Mixing

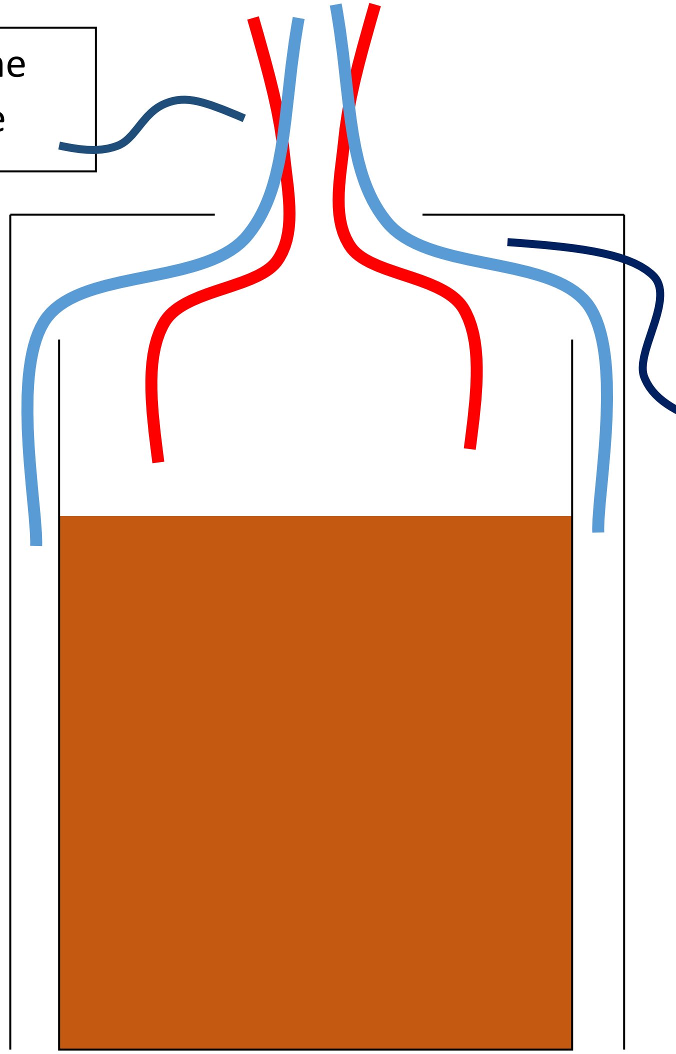
The random motion of the molecules in the gasses gradually, by random chance, mixes the gasses.

Concentrator mixing

The gas and air can be brought together and mixed by passing them through a reduced diameter hole in a metal plate, a concentrator. Excellent choice for mass, low cost production.

Concentrator mixing

Good mixing within the designed power range



Advantages:

- Simple and easy to build
- Inexpensive
- Effective within its designed power range

Disadvantages:

- Limited power range, due to backwards pressure gradients

More gas = too little air

As the power level and pyrolysis gas increases, the pressure under the concentrator increases, resisting secondary air entry, the mix is to rich, and smoke and soot form

Less gas = too much air

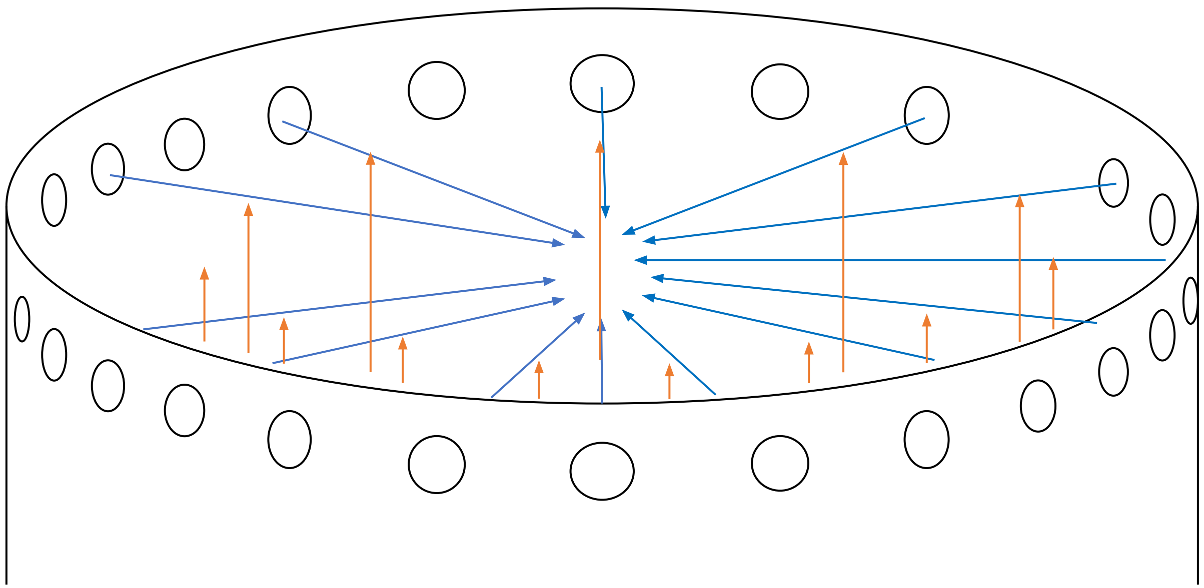
As the power level and gas decreases the pressure decreases, letting in too much secondary air, the mix is too lean and cool, and the flame is extinguished

Air Stream mixing

A commonly used TLUD mixing technique is the air stream technique. It is important to cover as much of the chamber as possible with flame, to ignite all of the rising gas.

This technique has a pressure gradient problem in that it is the air that is accelerated (instead of the gas), dropping its Venturi created pressure closer to the gas pressure, reducing the pressure gradient, and hindering mixing.

Another problem is the large penetration depth which is the radius of the chamber.



Pressure Gradient Mixing

Gasses flow from higher-pressure to lower-pressure, following the pressure gradient. The greater the pressure difference, the greater the force driving the flow. In a TLUD, as in any flame, the pyrolysis gas pressure is lower than atmospheric air pressure, forming a pressure gradient which the secondary air follows into the stove, penetrating into and blending with the gas.

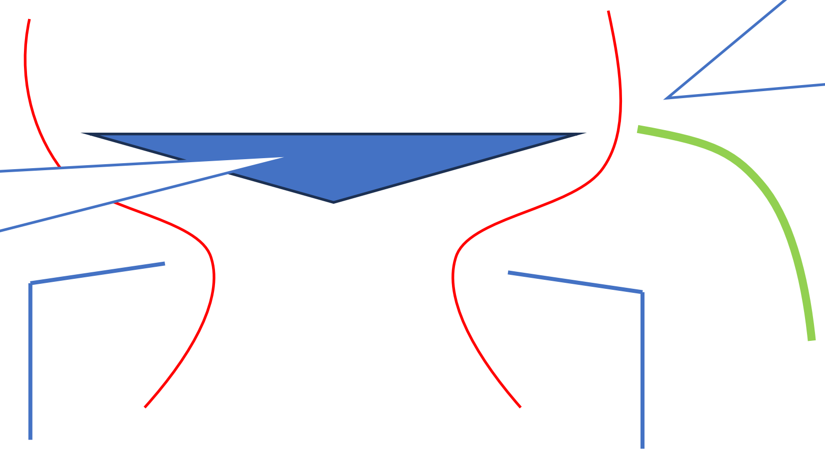
Pressure gradient mixing includes any mechanism which creates or increases the pressure difference between the gasses.

Sources of pressure gradients:

- The draft (buoyancy)
- The Venturi effect
- Forced air
- Wind
- Flow resistance

Bluff body Venturi mixing

A bluff body placed in the gas flow can affect local pressures.



A Venturi low pressure area is created here as the gas accelerates around the bluff body. Injecting the secondary air here uses the increased pressure gradient to improve mixing.

The case for Venturi bluff body mixing:

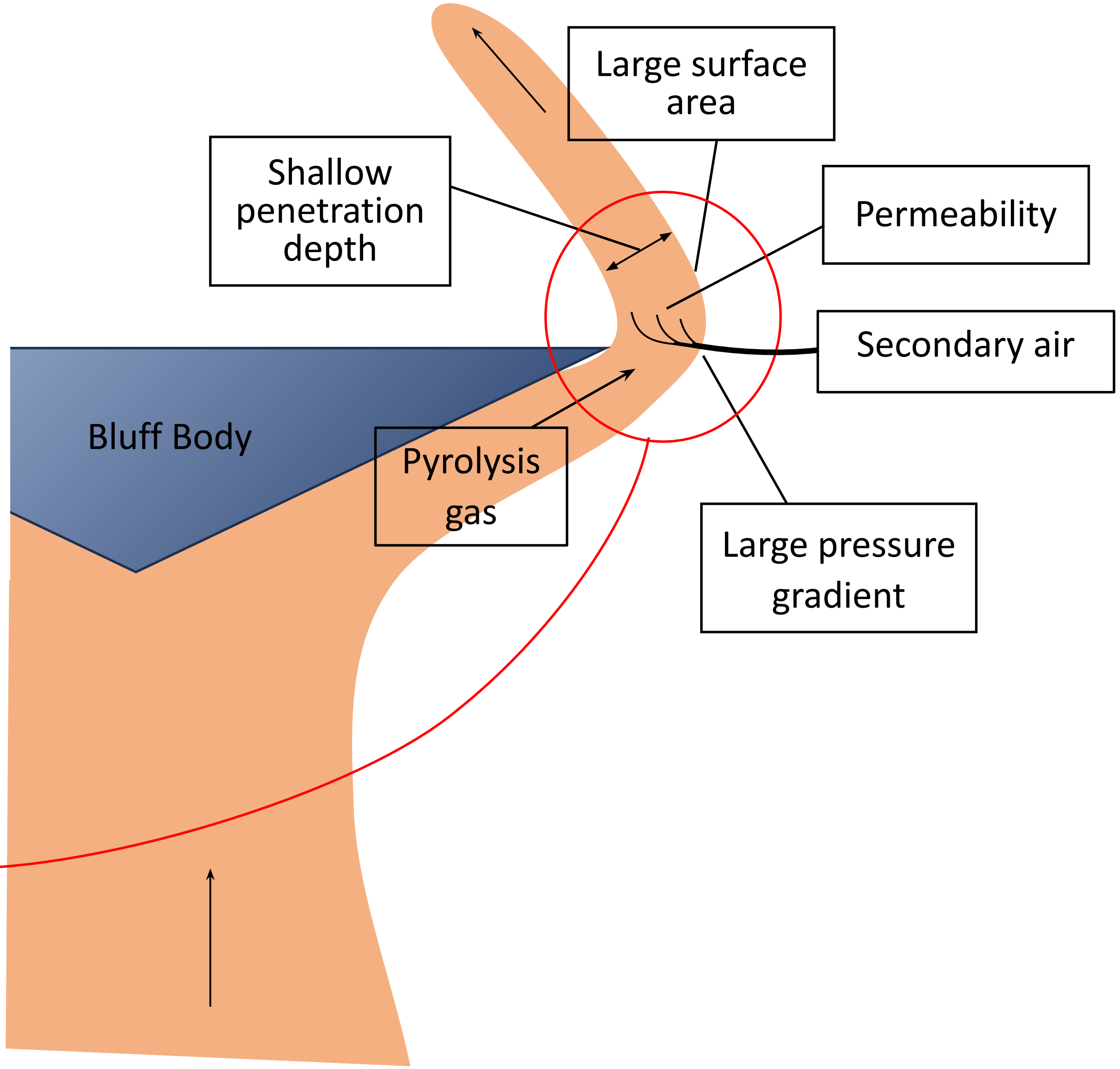
Strengths:

- Large surface contact
- Shallow depth of penetration
- Increased pressure gradient
- Rapid mixing

Weaknesses:

- Double bluff body takes time and space to mix

Bluff body Venturi mixing is something like Just-In-Time manufacturing. Everything needed for complete mixing arrives at the mixing point at the same time. The gas can rapidly mix with the air and burn very quickly.



A Brief History of the Flame Spreader

The bluff body burner is not a new way of burning. Its first recorded use is from 1857 when a flame spreading device was attached to the wick of a coal oil lamp, so there is historical precedence for its use. What is new is its adaptation to the TLUD cooking stove.

Several flame spreaders similar to those used in the nineteenth century.

A nineteenth century wick burner with a flame spreader at the top.

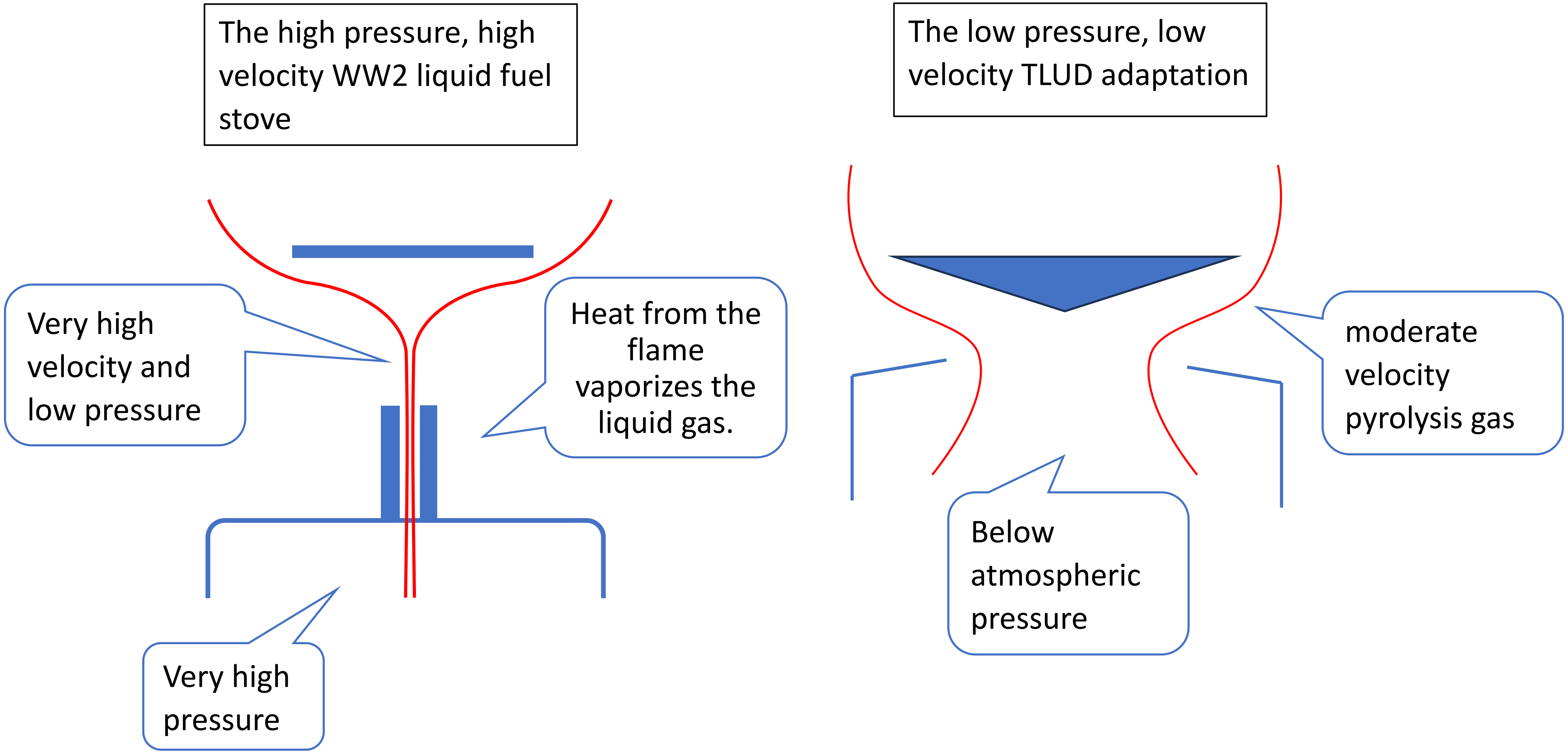
Designs using pressurized liquid gas and flame spreaders, were used in World War 2 by USA, British, French, and German field stoves.

A WW1 wick type trench stove with no flame spreader. Very slow cooking.

A WW2 circa 1942 U.S. field stove with a flame spreader.

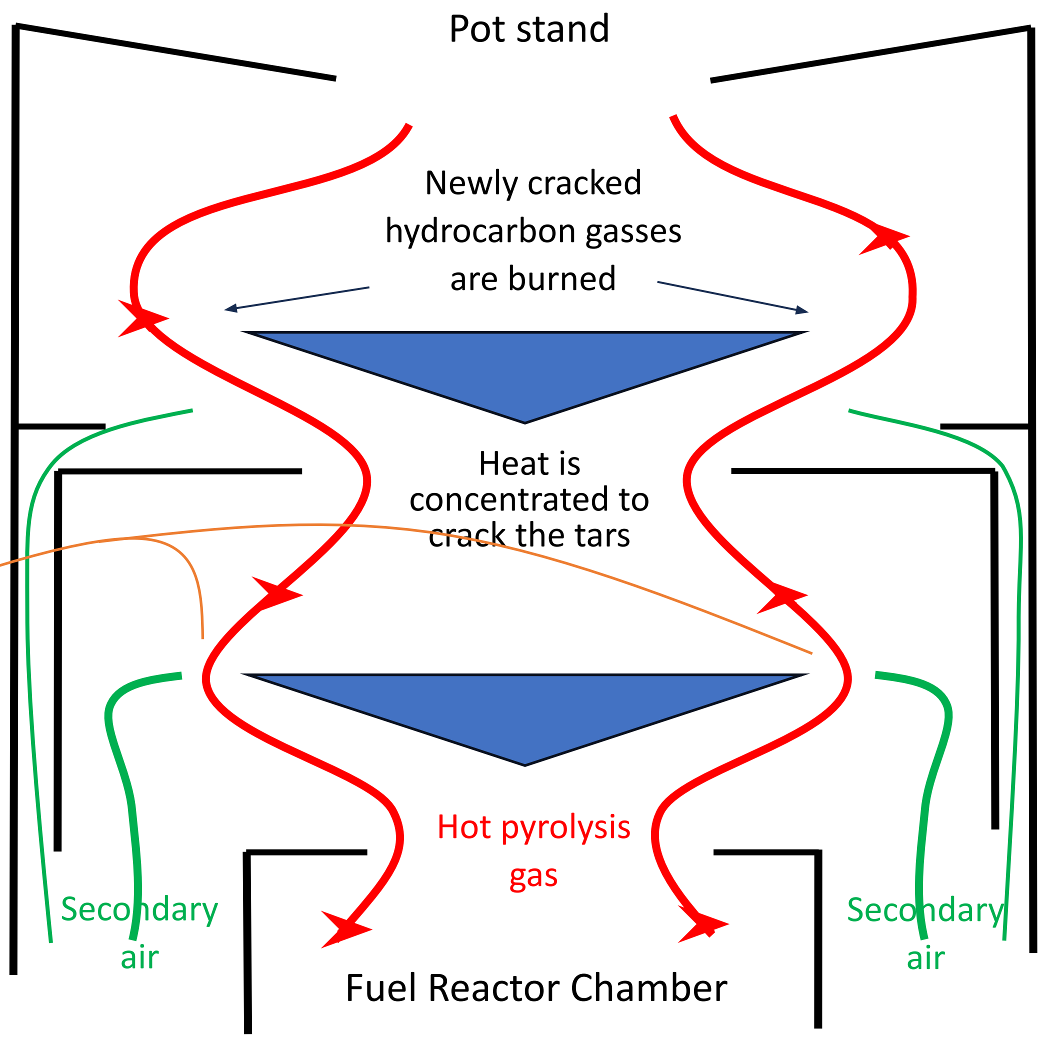
A WW2 German flame spreader plate.

Adapting the flame spreader to the TLUD stove



Double bluff body burner

The double bluff body burner is designed to crack and burn the tars in the pyrolysis gas.



Low pressure area where the easy to burn gasses (CO, H_2, CH_4) are rapidly burned

I have not had any problems with too much secondary air at the lower bluff body, but the upper bluff body flame is sensitive to excess secondary air.

Excessive High Power Video

This slide shows the effectiveness of the double bluff body burner. In this video, forced primary air creates excessive pyrolysis gas, and the double bluff body **natural draft** burner can keep up.

A more extensive document
is included here.

Microsoft Word
Document