Update

Wonderwerk 316 → Wonderwerk 918

Thank you to Paul Anderson, Ron Larson, Dean Still and the ARC staff, Julien Winter, Vi Rapp, and all who have helped and supported me over these last several years while developing the Wonderwerk stoves.

The Wonderwerk 316 TLUD-ND wood stove is a tier 4 stove. At medium power levels it could burned soft wood pellets at almost 100% efficiency. It did have some problems:

1. It could not burn clean at very high-power levels.
2. It had turn-down to about ¼ power, but not with stability.
3. It had some delicate parts which could be easily damaged.
4. Some of these parts could not be easily repaired or replaced in the field.
5. It could not transition cleanly from hydrocarbon to charcoal flames except at high-power levels.

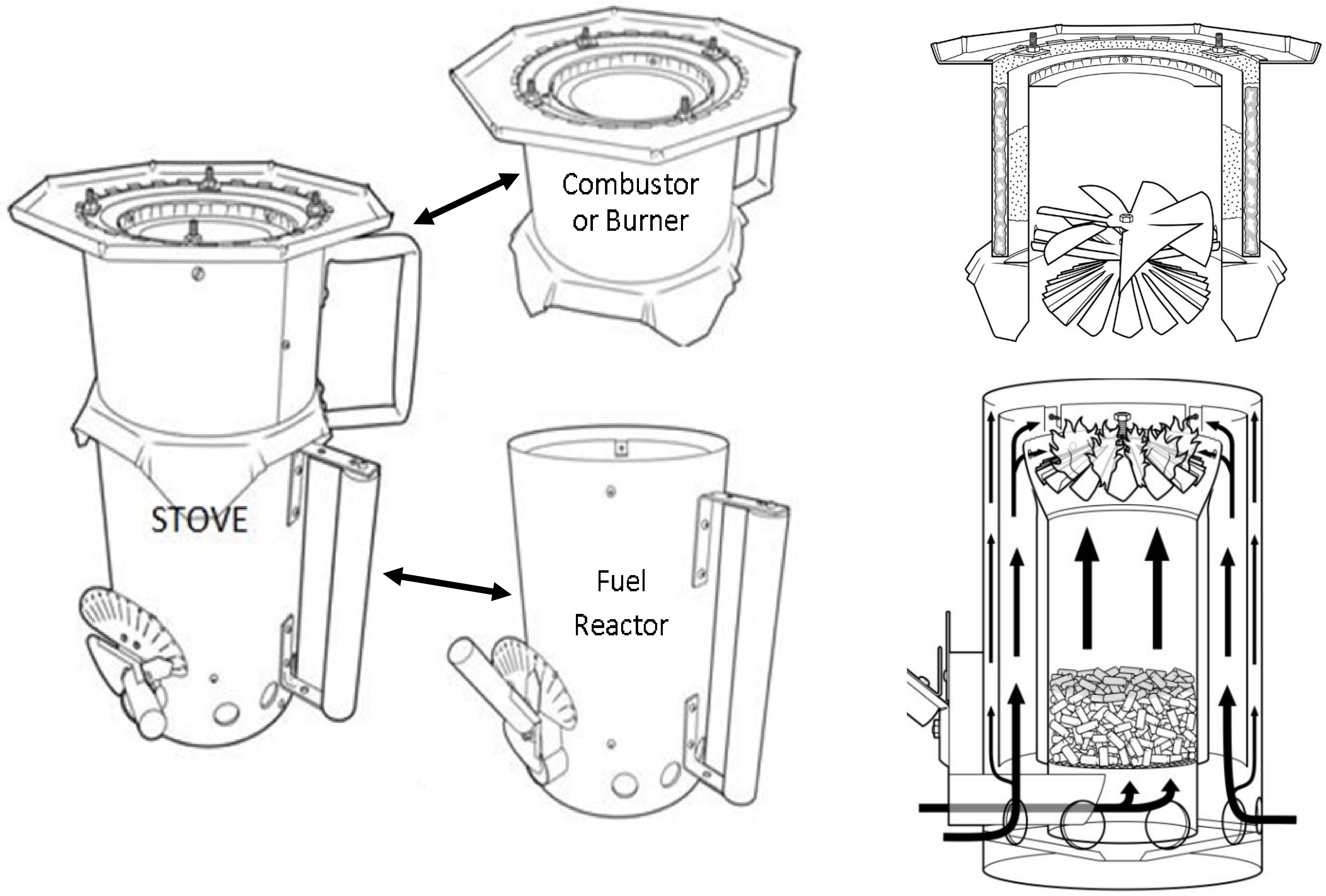
The Wonderwerk 918 addresses these problems:

1. It burns cleanly at full high-power.
2. It holds a stable ¼ power flame.
3. The structure is simpler and sturdier
4. Worn parts can easily be replaced in the field.
5. It can cleanly transition to coals from high to medium-low power levels, and is cleaner at low power levels.

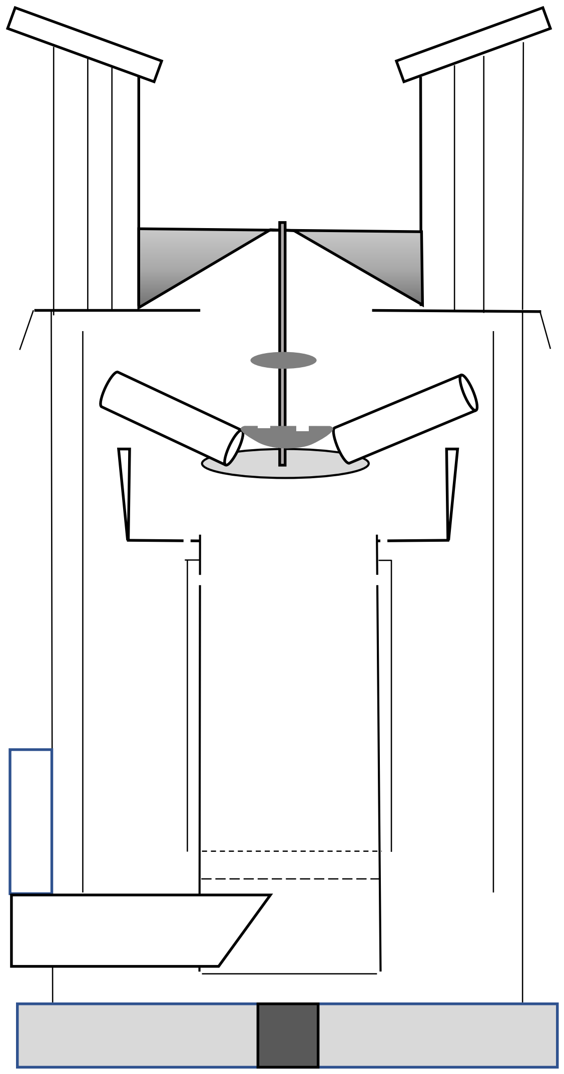
Some good things about the 316 burners that should be kept and enhanced while solving its drawbacks?

1. At high power levels it has large surface contact between the wood gas and secondary air and the small depth of penetration that the gasses need to penetrate into each other, leading to rapid and thorough mixing.
2. An enhanced pressure difference between the wood gas and secondary air, created by the buoyant force and Venturi effect, that helps mix the gasses
3. Low enough flow resistance that the low-power flame can function.
4. Multiple burners that work together for a clean burn.
5. Variable power levels

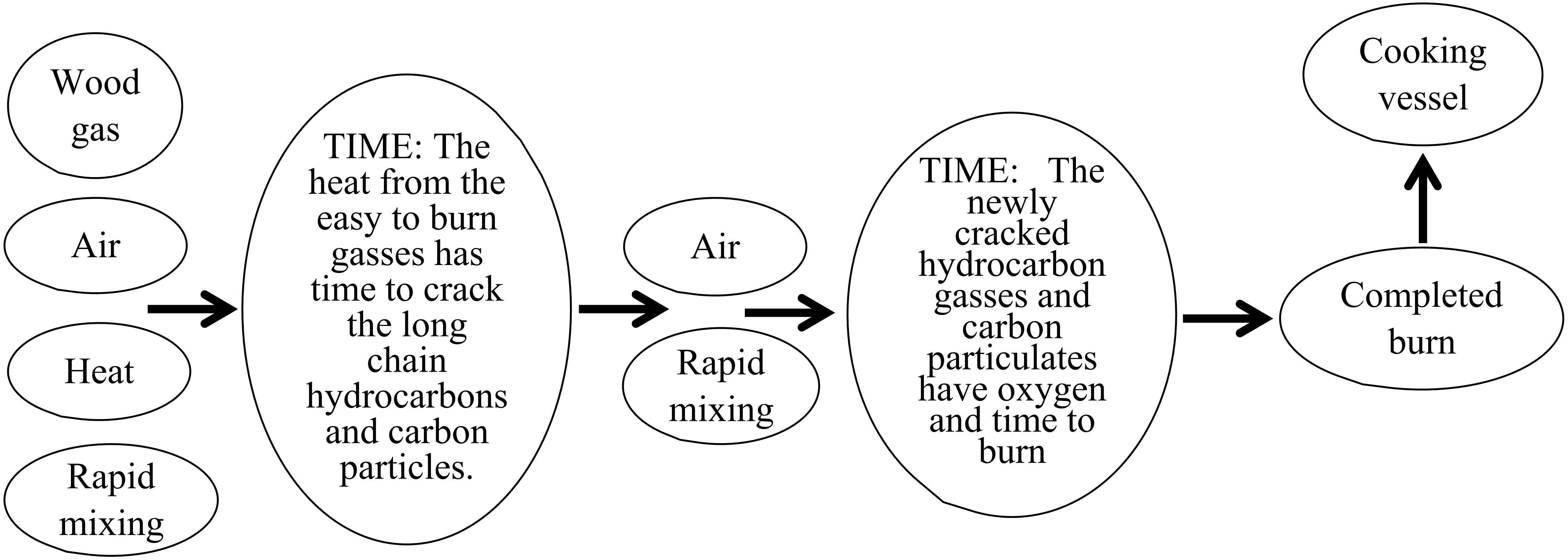
Wonderwerk 316



Wonderwerk 918

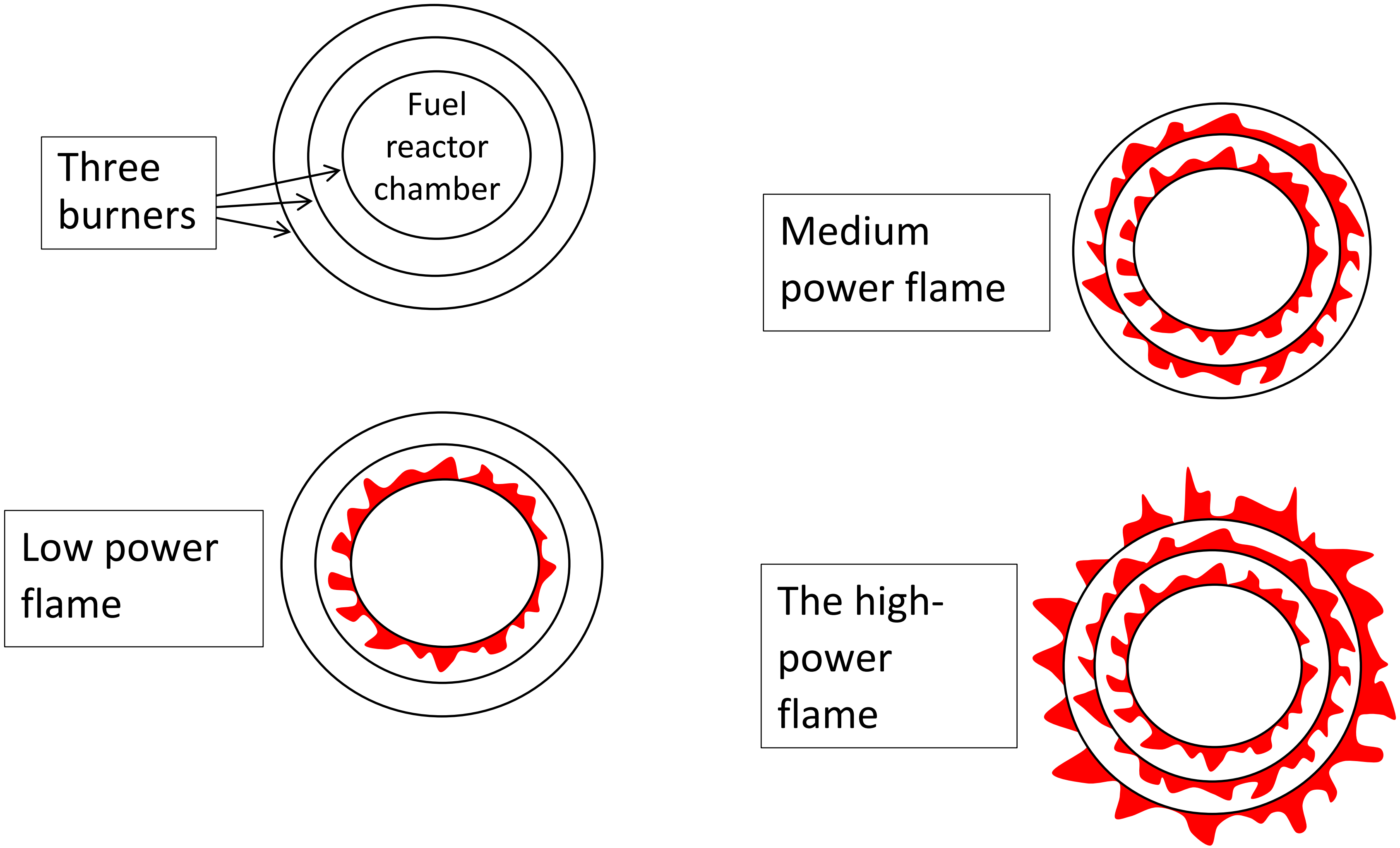


Wood gas is a dirty gas containing long chain hydrocarbons, carbon particles, and ash as well as easy to burn gasses. This flow chart shows a simplification of how to cleanly burn wood gas so that only the nonflammable ash exits the stove.

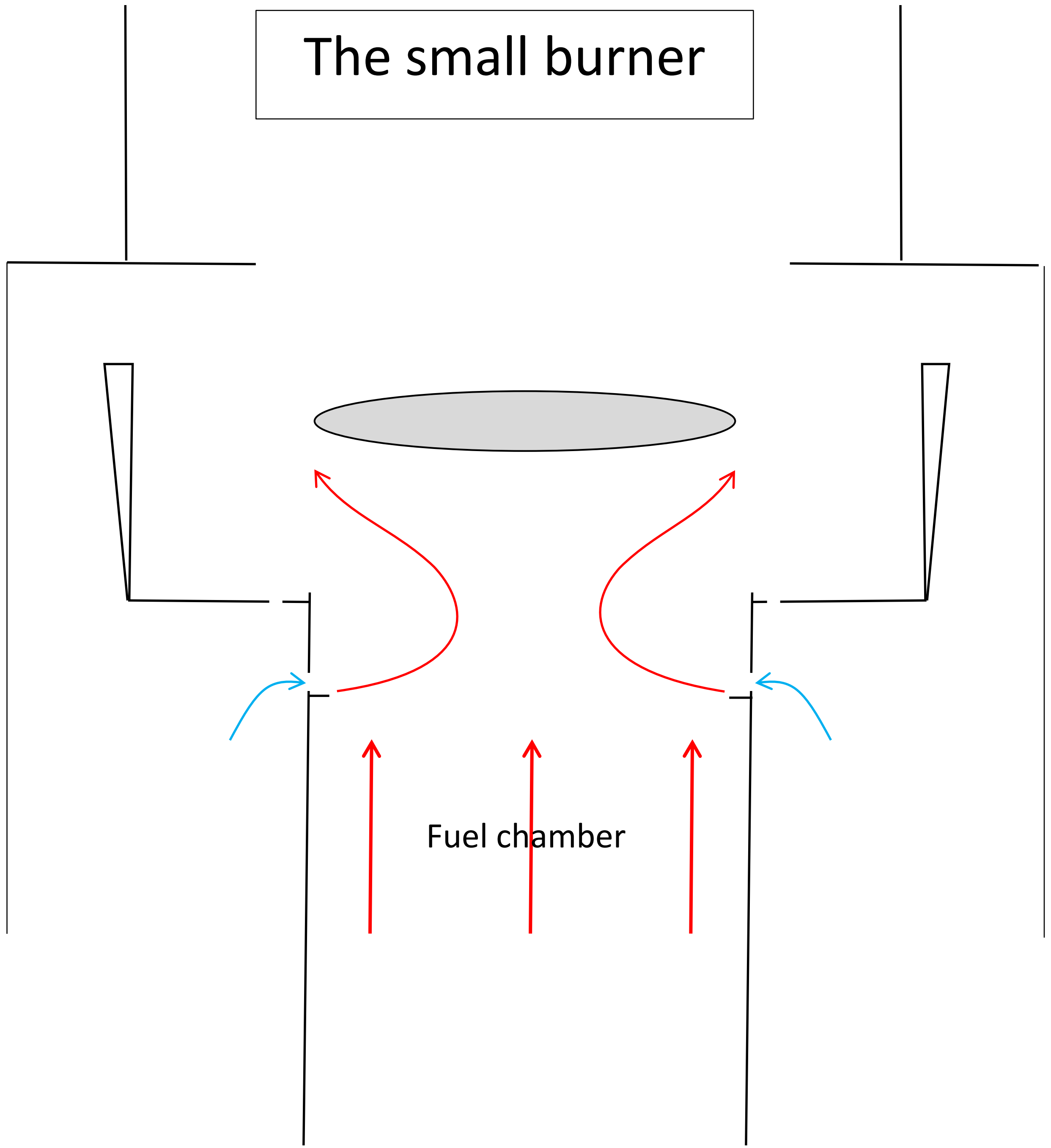


Rapid mixing, part 1: the Wonderwerk 918 uses additive burners

1. Multiple concentric burners are sized for each size flame.
2. They work together preheating and igniting wood gas for the next burner and cleaning up for the previous burner.

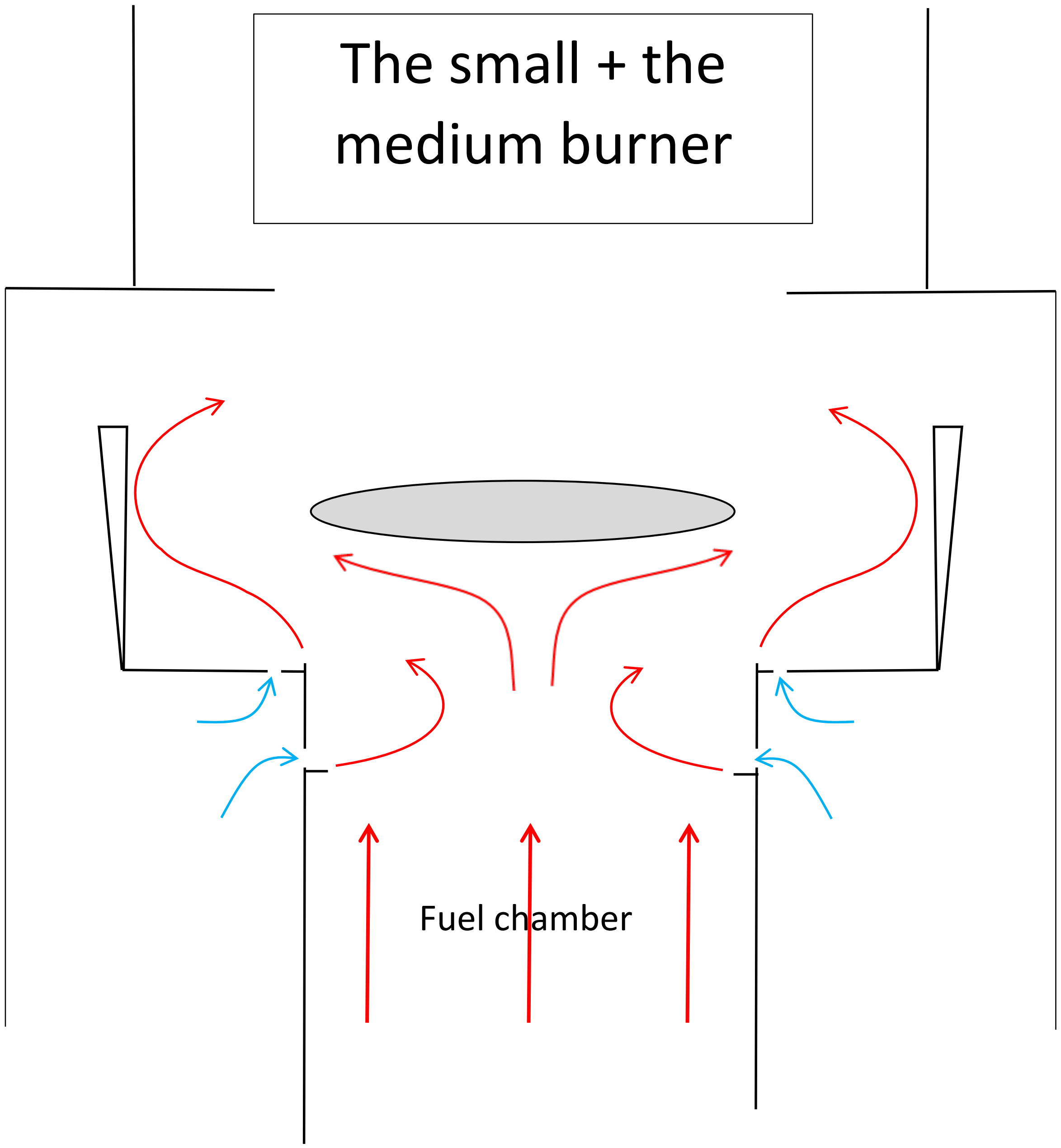


The small burner



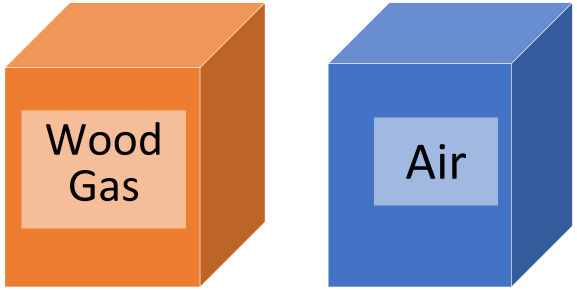
The large disk is the same diameter as the fuel chamber. At low-power levels it helps keep cool secondary air from falling into the fuel chamber and extinguishing the flame.

The small + the medium burner

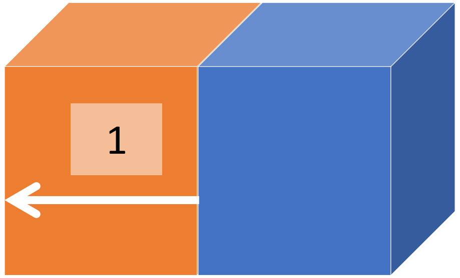


At medium power the large disk directs the wood gas outward to meet the air at the medium burner.

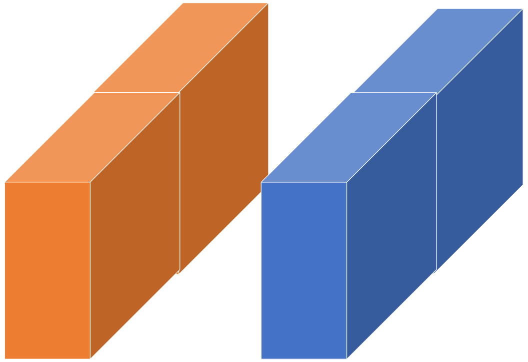
Rapid mixing part 2, Surface Contact and Penetration Depth



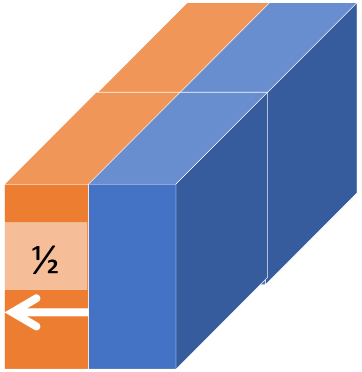
Bringing them together gives 1 in^2 contact surface and 1 in needed penetration depth



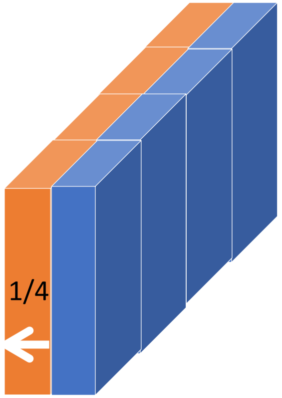
Dividing the cubes in half



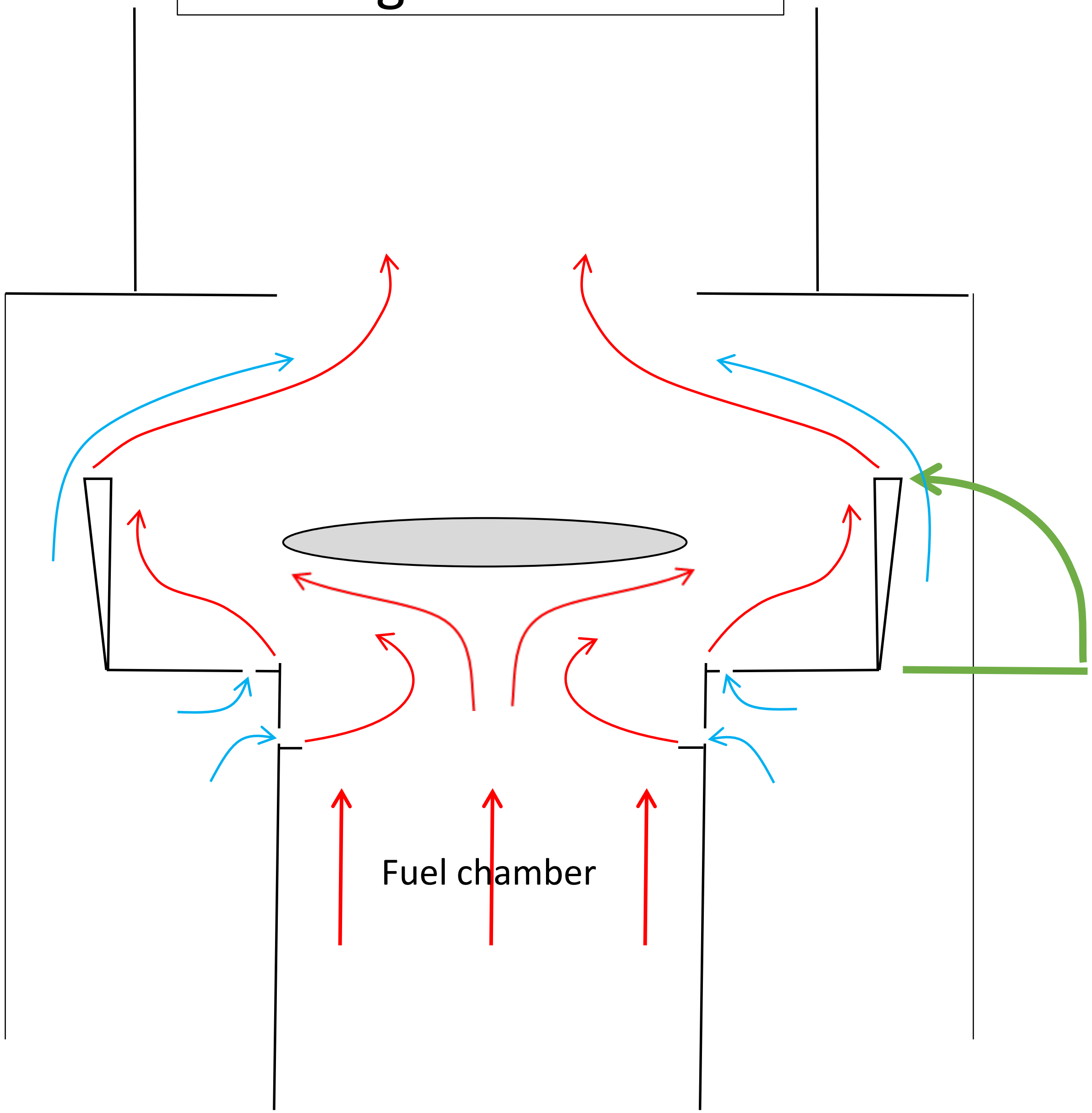
Bringing them together gives twice the flame size and half the penetration depth needed



Spreading them again gives 4 times the flame size and ¼ the needed penetration depth, resulting in a much larger and hotter flame that finishes burning much faster.



The small + medium + large burners



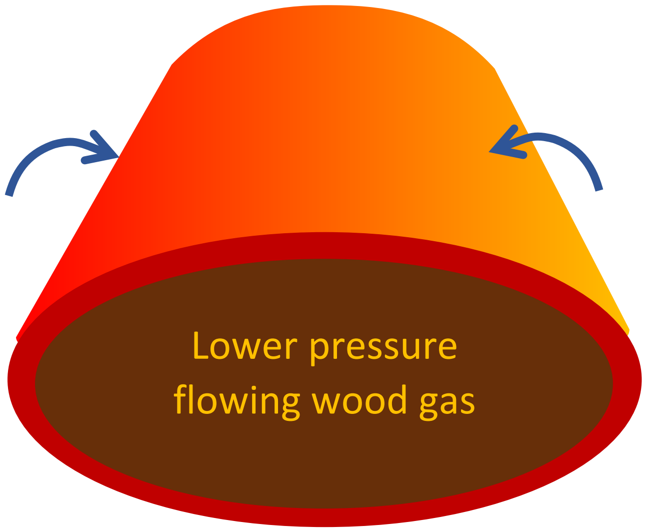
The bent up edge is corrugated, giving 10 x 3.14 inches of mixing edge.

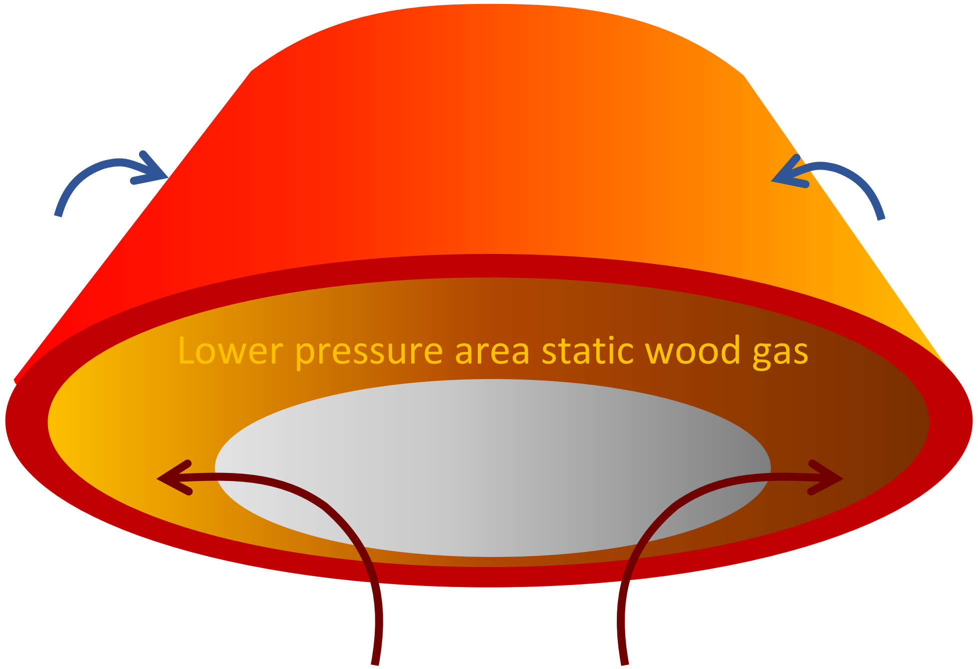
At high power levels the large disk directs the wood gas outward to meet the large burner secondary air, helping to increase the surface contact between the wood gas and the secondary air.

Funnel shaped large flame

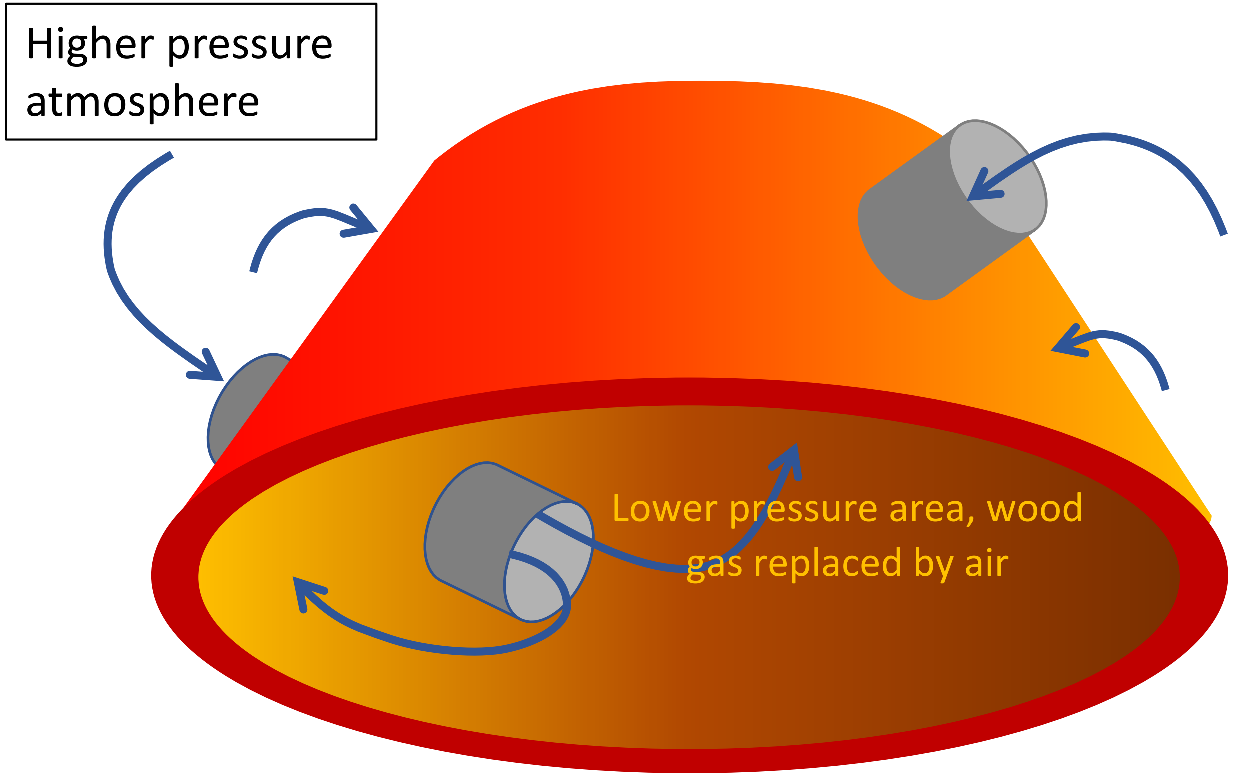
A common diffusion flame will burn only at the surface where the gas meets the air.

The large plate spreads the wood gas, increasing the surface contact

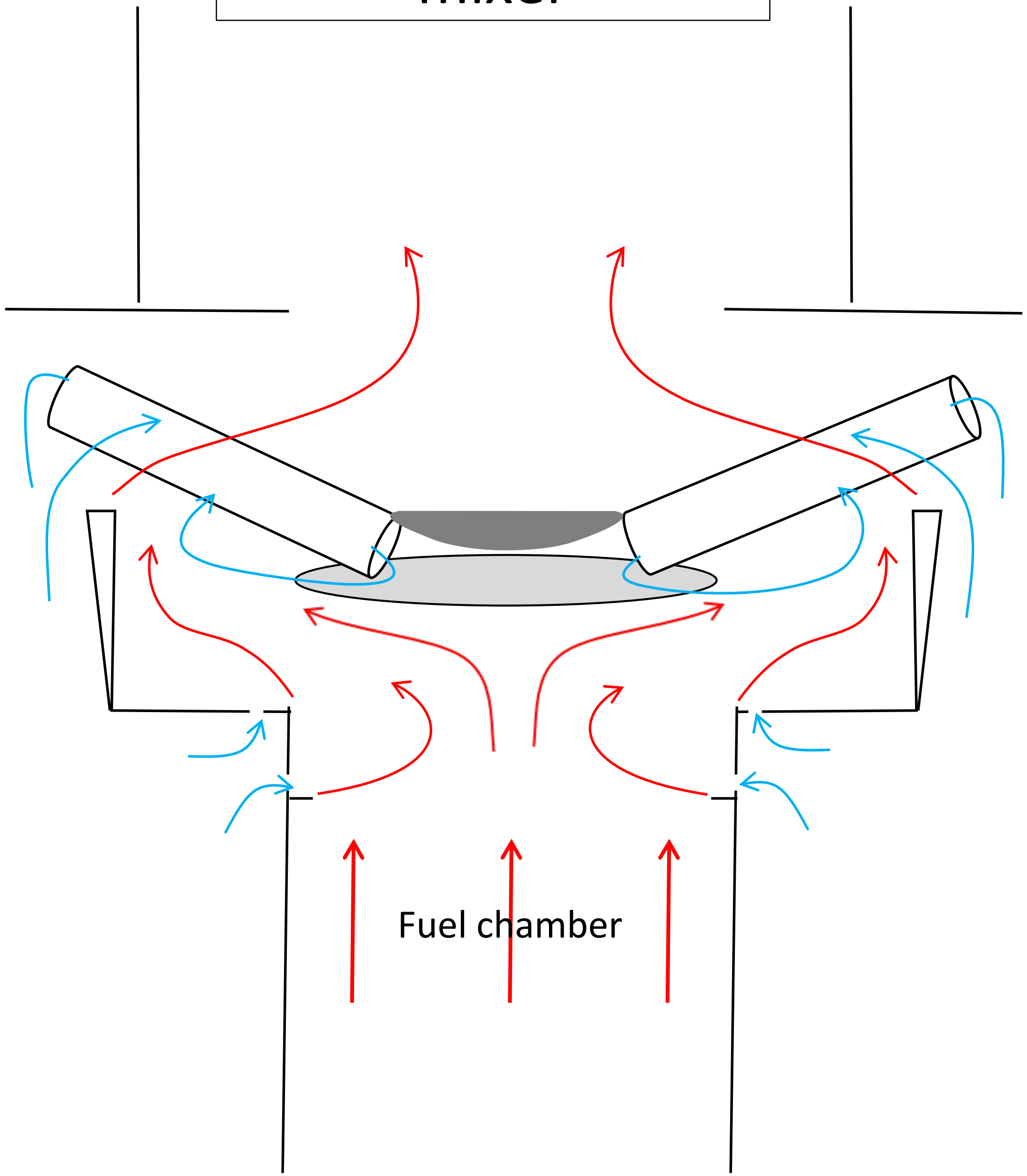




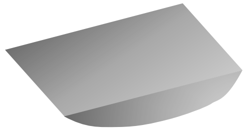
Higher pressure air pushes through the tubes to feed the flame from the inside, almost doubling the surface contact



Adding the inside mixer



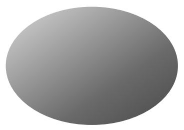
Bent down edges gives better spreading of the air.



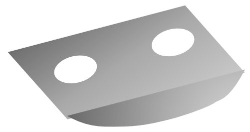
At high-power levels the large disk helps to direct the inside air outward to meet the gas.

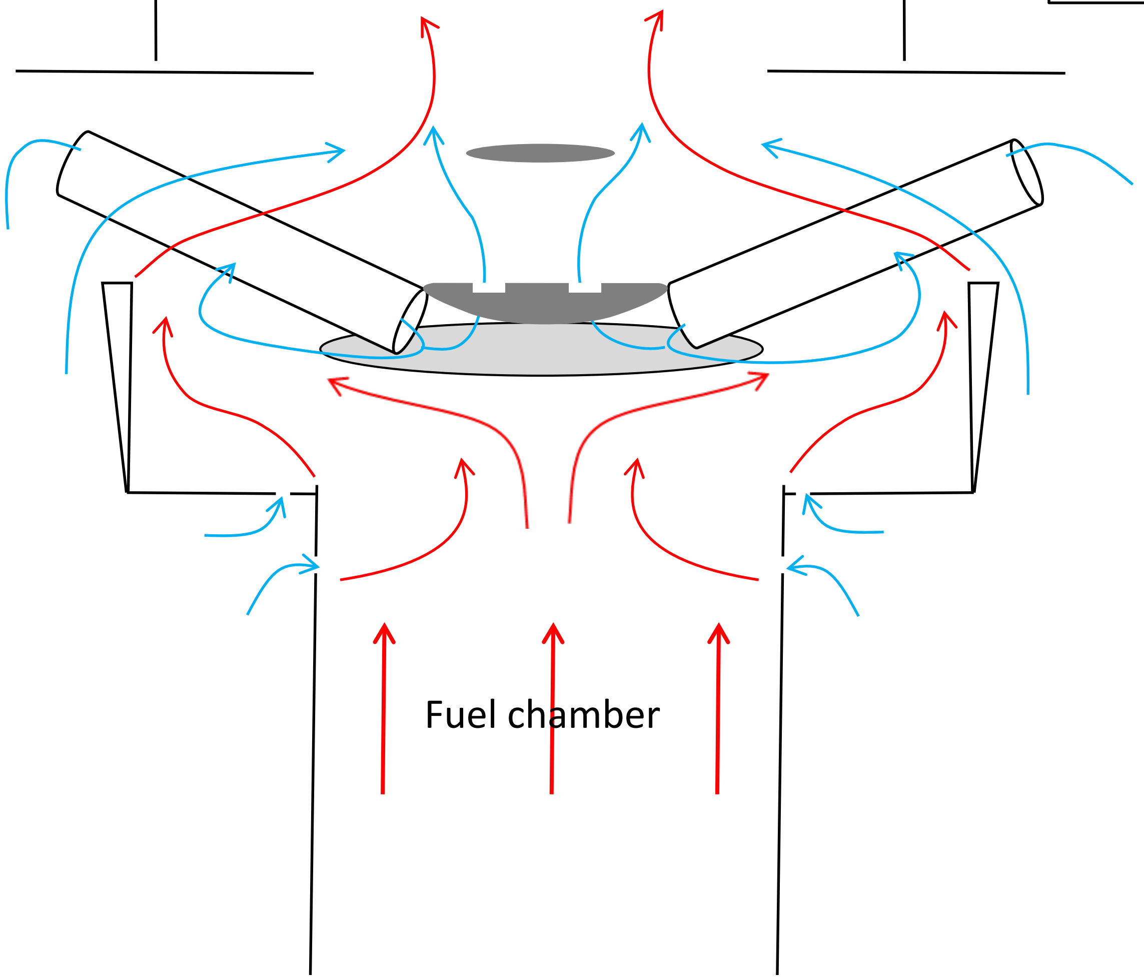
Adding the clean-up mixer

The clean-up burner disk

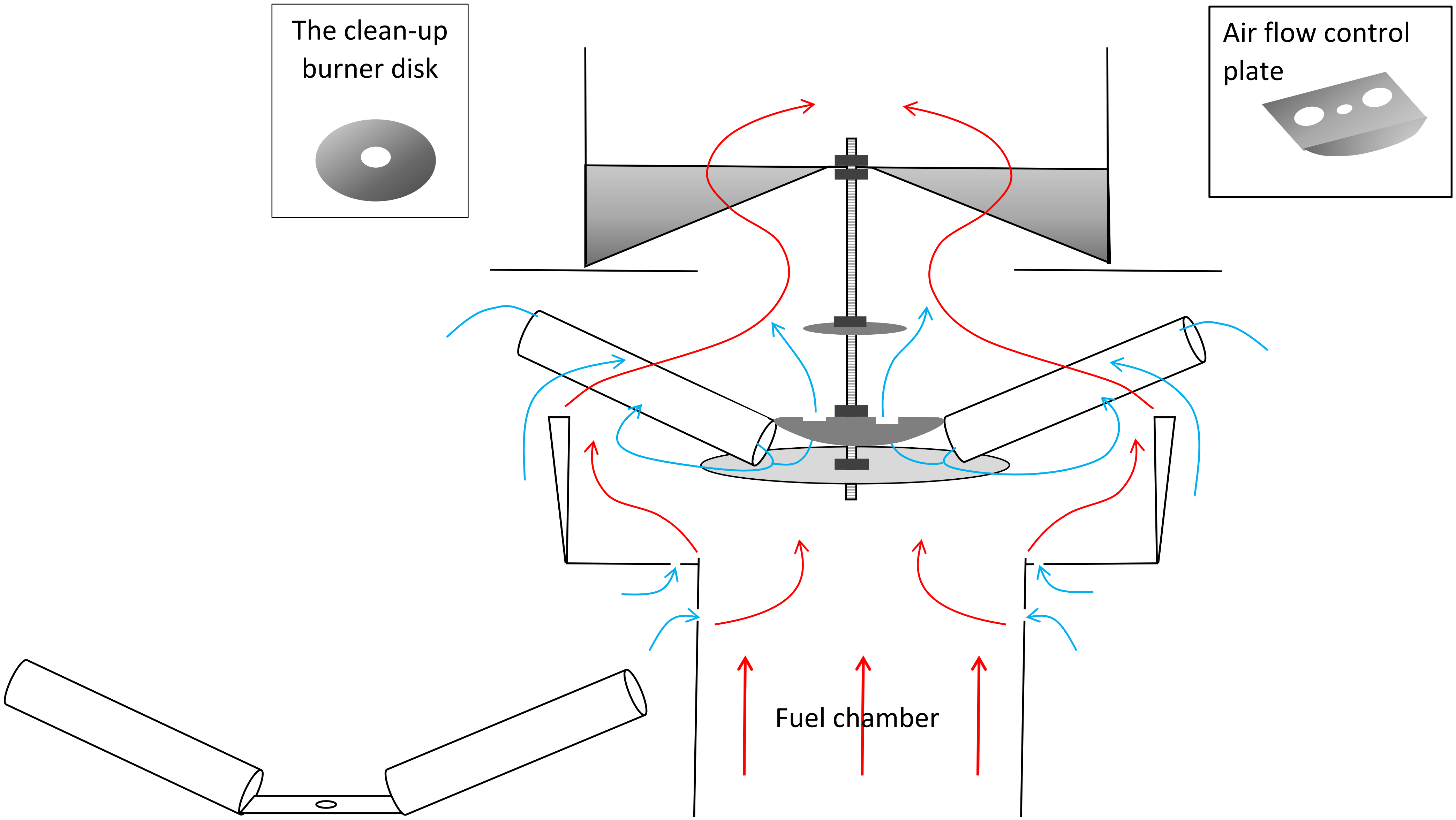


Add holes for clean-up burner



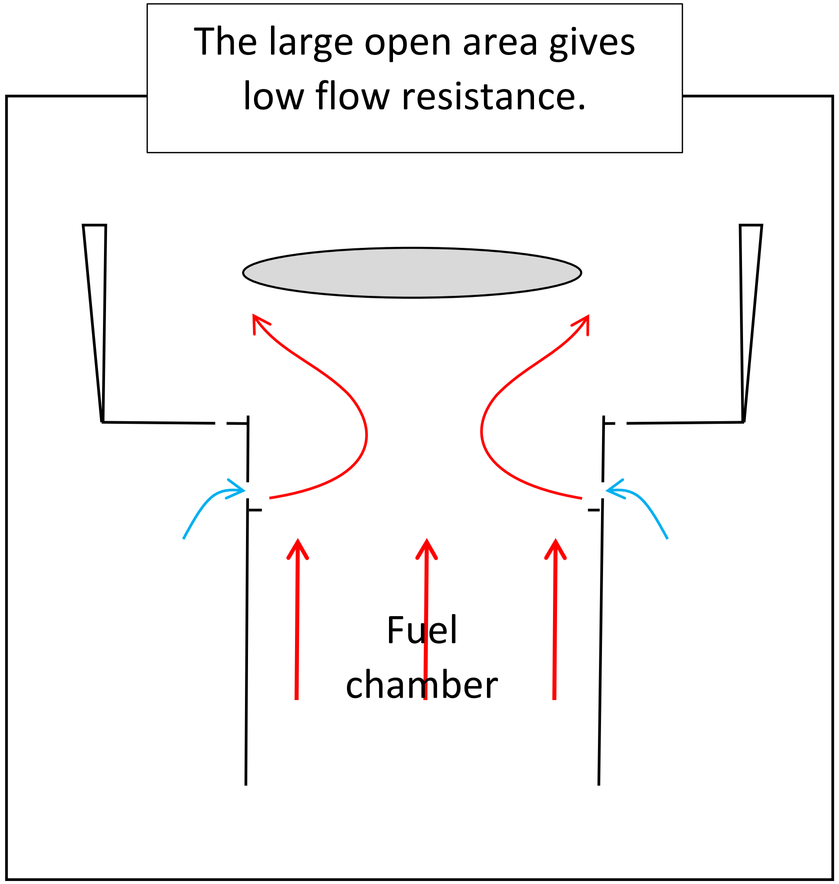


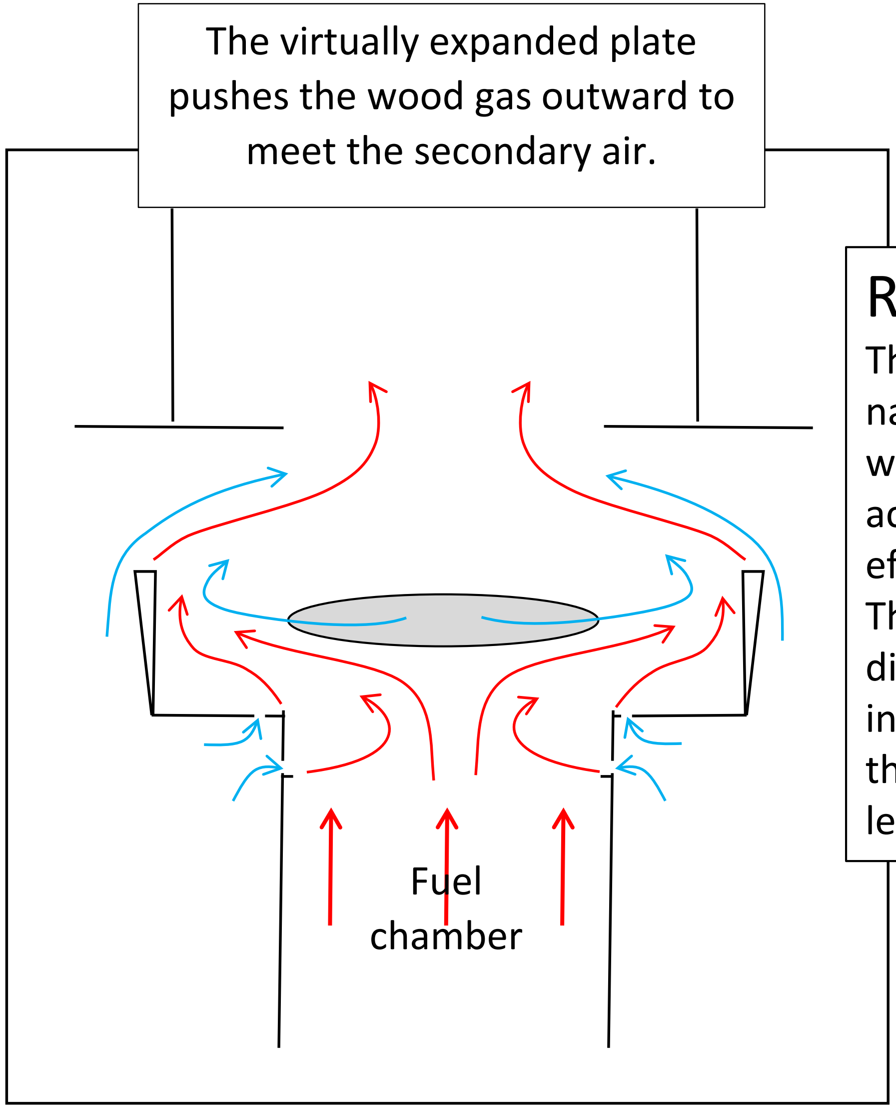
Adding the central shaft and stationary fan



Virtually Self-adjusting disk:

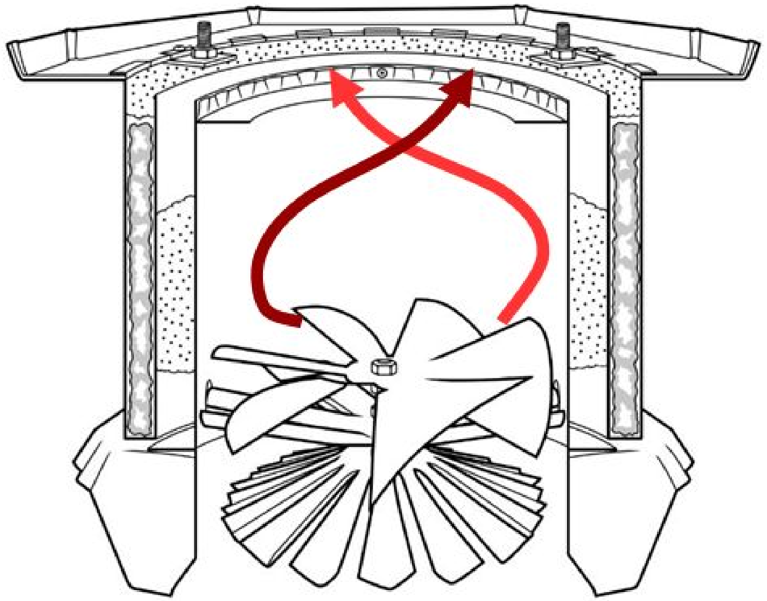
Variable flow resistance helps both low and high-power flame.





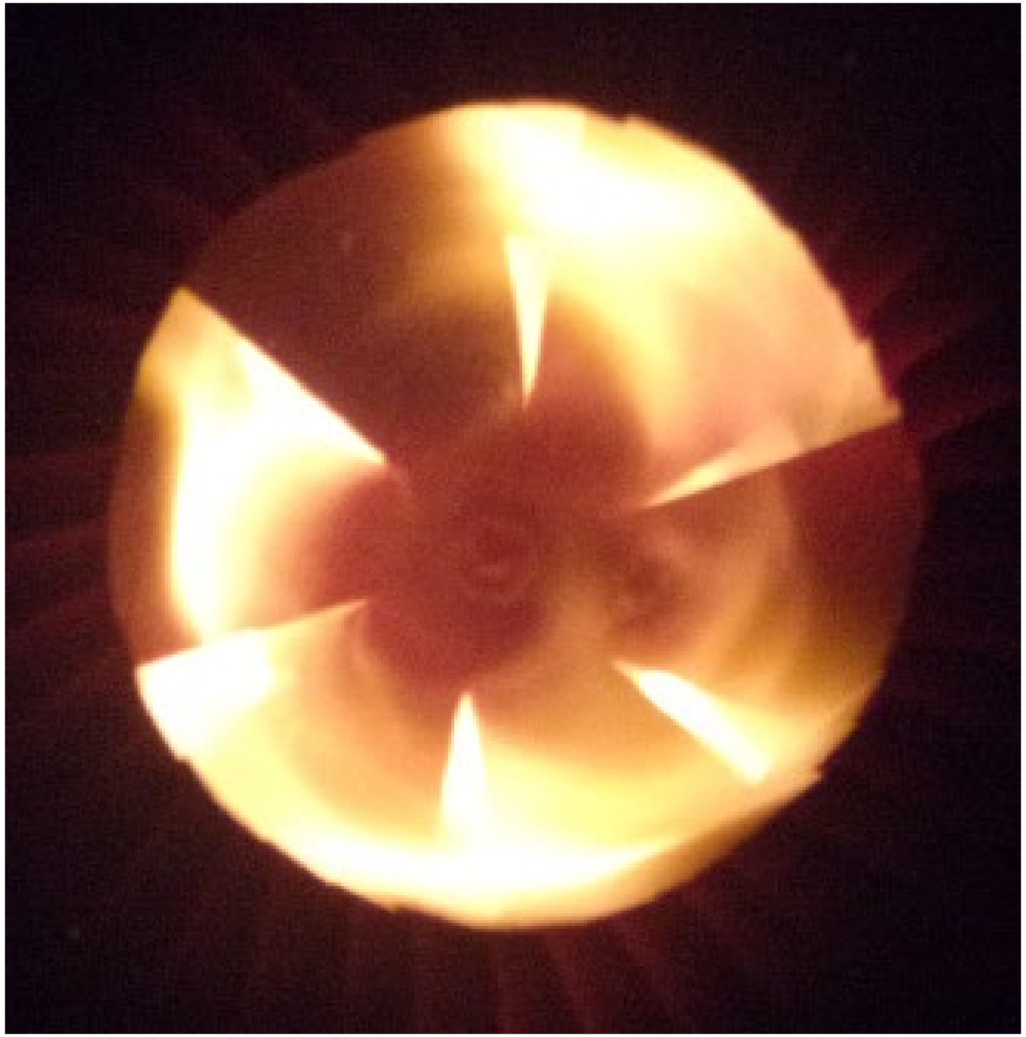
Rapid mixing part 3:

The virtually expanded plate narrows the gap where the wood gas can rise, forcing it to accelerate, and by the Venturi effect its pressure decreases. This increases its pressure difference with the air, increasing the force pushing the air into the wood gas and leading to more rapid mixing.



The Stationary Fan

A stationary fan blade swirls the flame giving it more time to burn, and also compacts the flame to keep it hot.

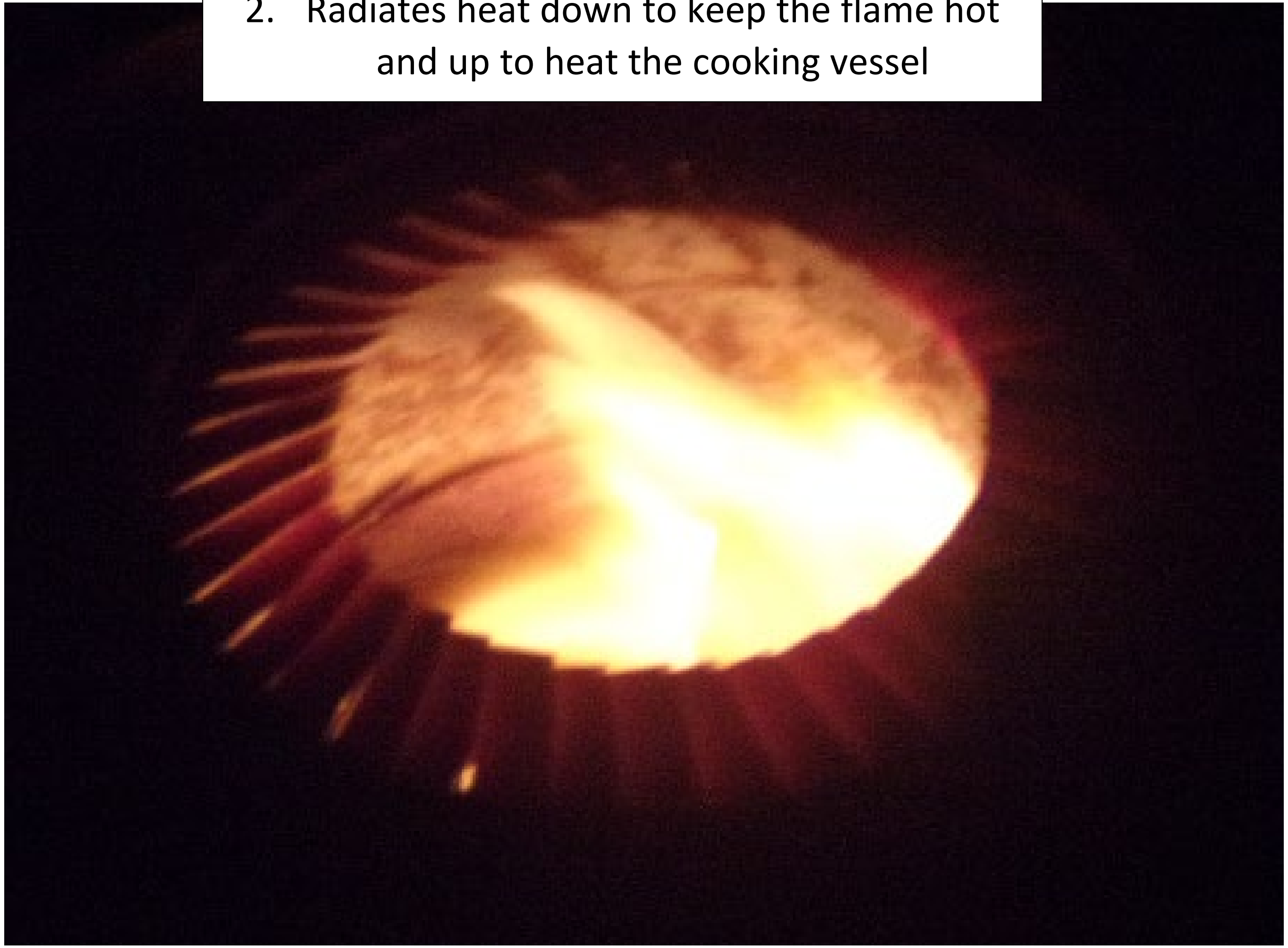


Heat

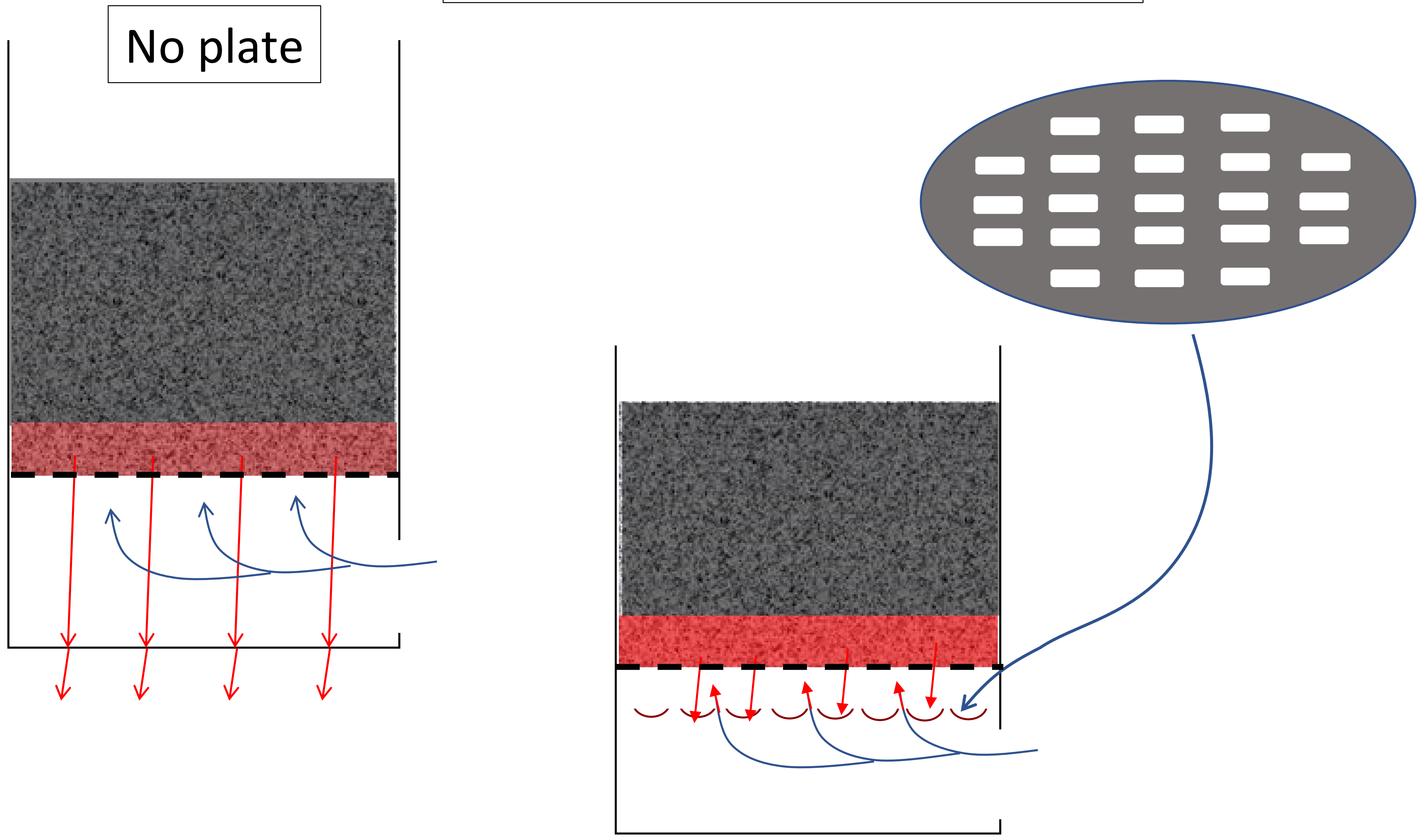
1. Burning the easy to burn gasses rapidly via rapid mixing creates a concentrated reservoir of heat.
2. Long chain hydrocarbons pass through this reservoir of heat and are cracked into short chain flammable gasses. Cracking long chain hydrocarbons is endothermic, and so the above concentrated reservoir of heat, both in quality and quantity, is needed to feed it.
3. Swirling the flame with the stationary fan continues to concentrate the heat to complete the burning.
4. A flame cooled by hitting the cooking vessel may not finish burning and may form soot and smoke. The burning finishes before the gasses hit the cooking vessel.
5. Conservation of energy; the heat created by the flame cannot just disappear. Though no longer visible as flame, hot gasses from the completed burn at the bottom of the combustor will be just as hot at the top if no heat is lost along the way.

Radiant heating fins

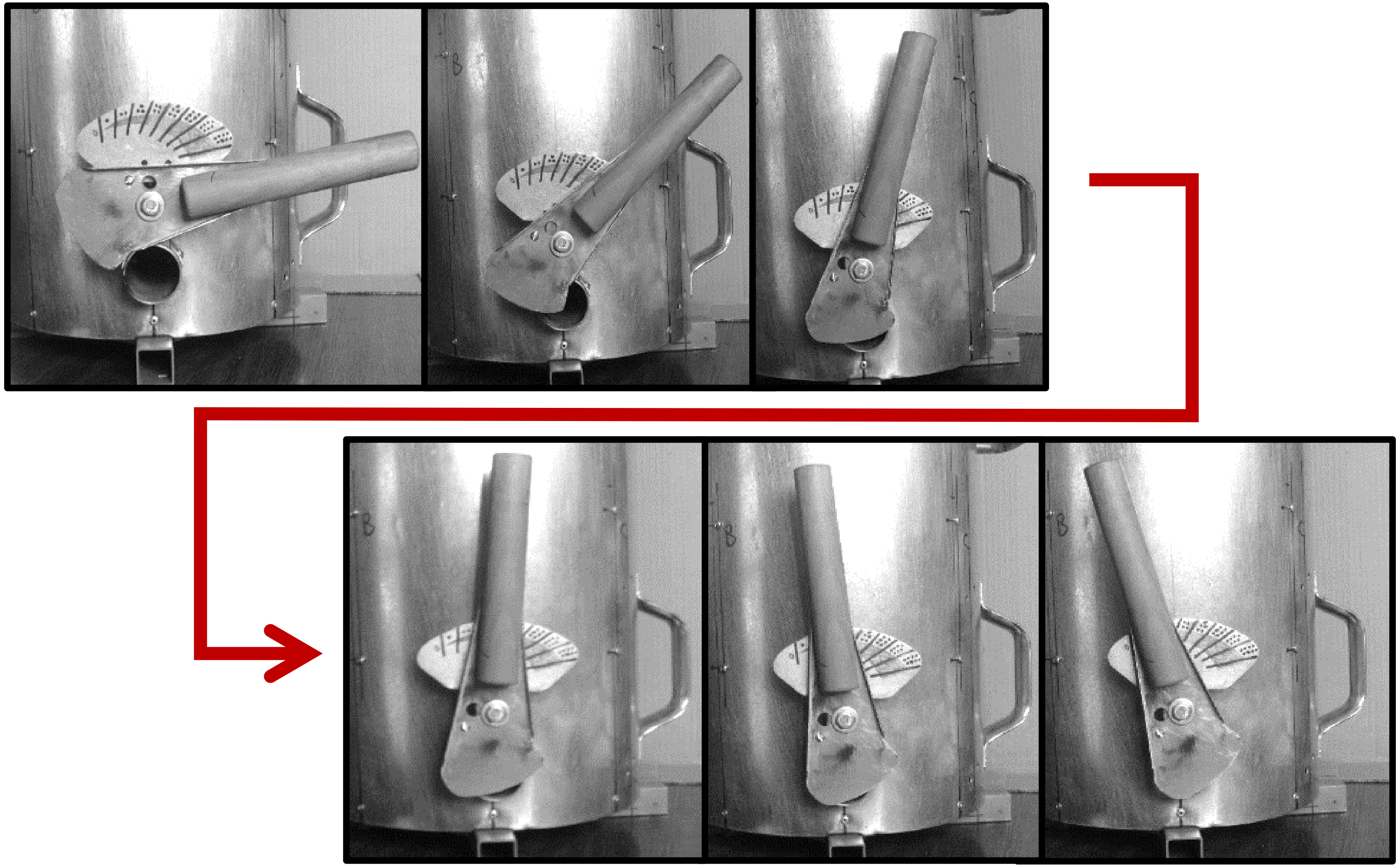
1. Balance between power level, and carbon monoxide combustion
2. Radiates heat down to keep the flame hot and up to heat the cooking vessel



A perforated plate promotes clean transition to char

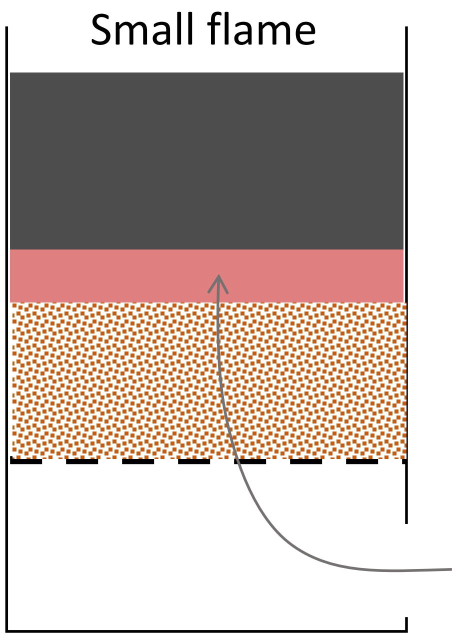


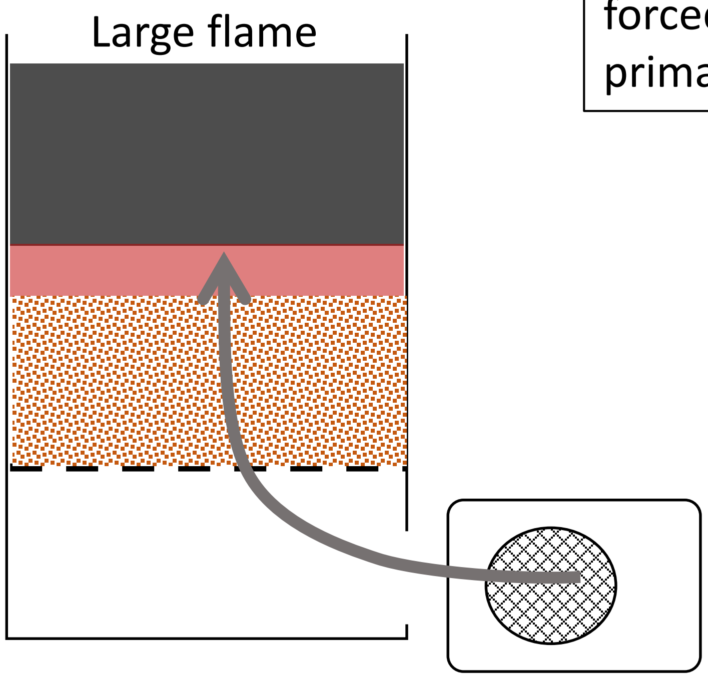
The primary air-control, power level adjustment:
The stove has turn-down too ¼ power



Transition to forced air:

A small battery powered cooling fan can give forced primary air to overcome flow resistance from a tall fuel stack.

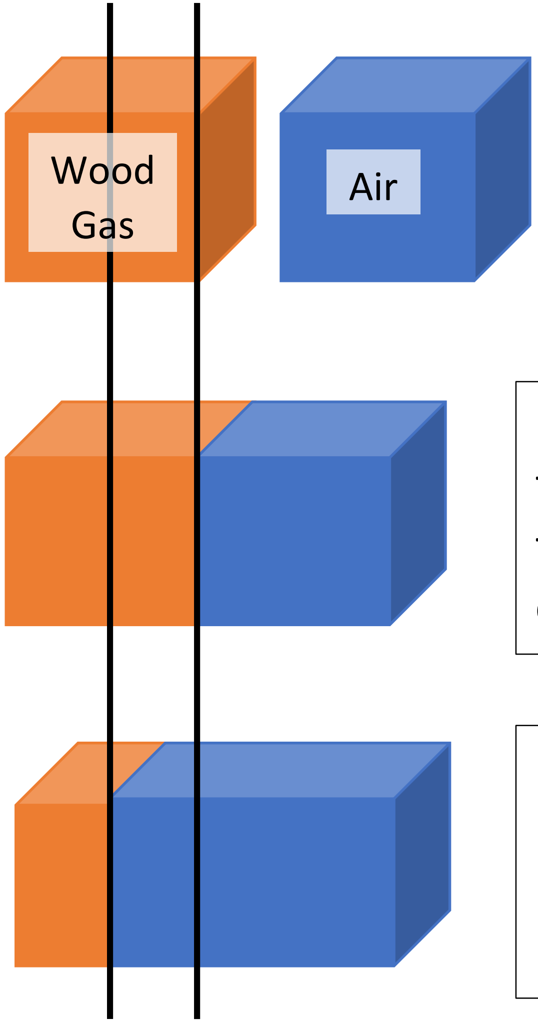




Too much forced primary air

Pressure Difference Hypothesis

Note: We do not have 1 cube of each gas. We have a virtually infinite supply of atmosphere and wood gas pushing continuously together. This description is only to communicate the general idea of injection.



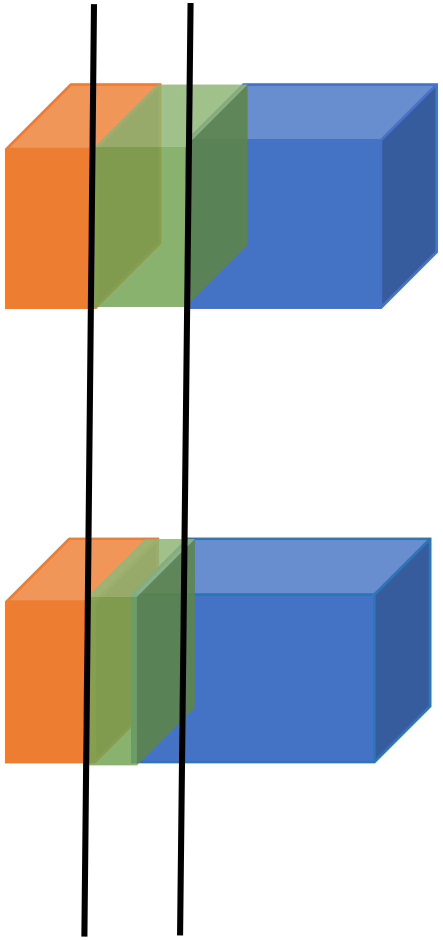
Higher pressure air and lower pressure wood gas

Bring them together and two things can happen:

1. Expansion of air and compression of wood gas

Or 2. because gasses are permeable, penetration, what I am calling injection

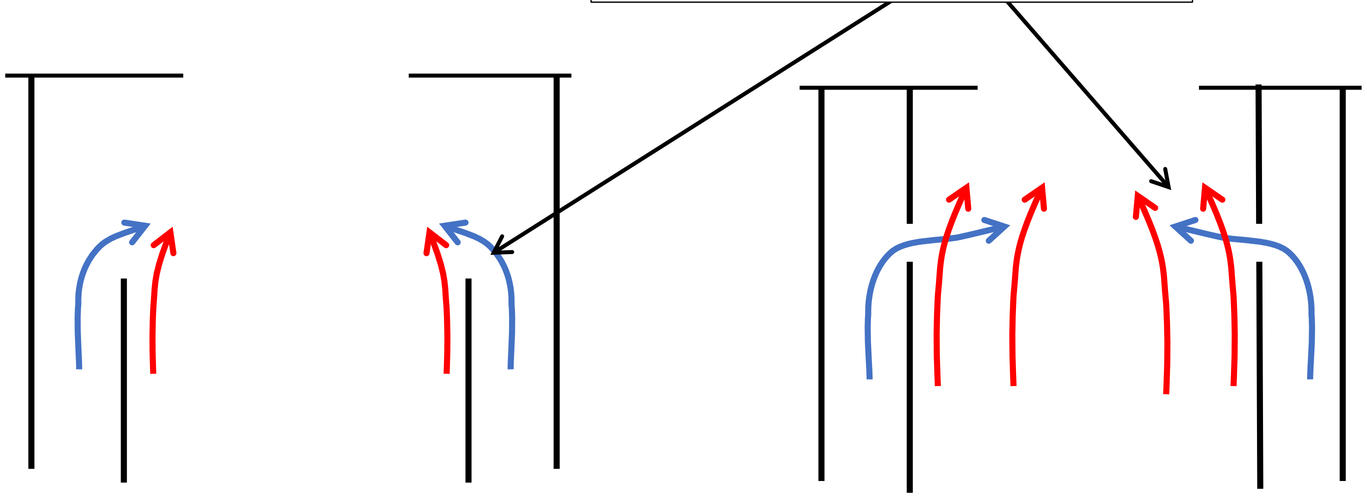
Some of both will happen



Injection is not new

It is common in all fires, including TLUD-ND stoves. Both edge and hole secondary air mixing designs use pressure driven injection.

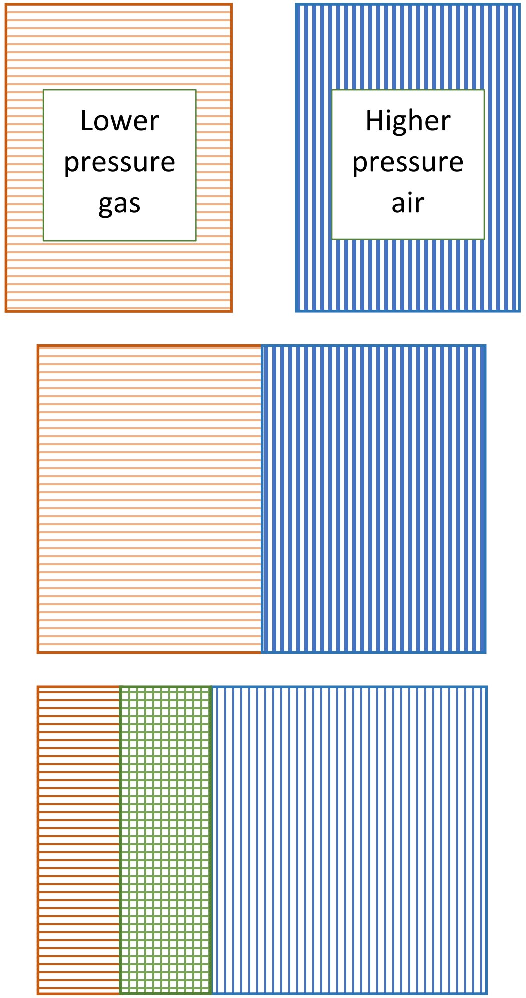
Higher pressure air pushes into the lower pressure wood gas.



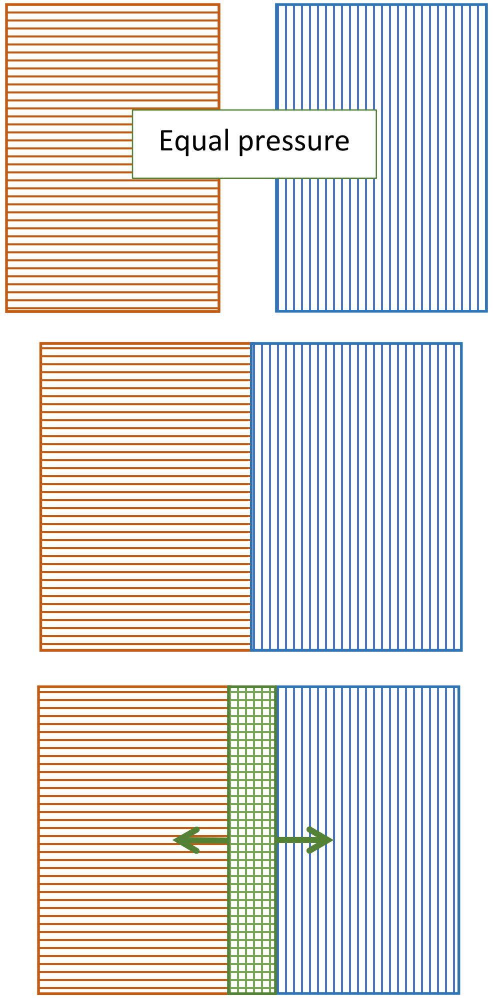
Injection vs. Diffusion hypothesis

Both injection and diffusion rely on the permeability of gasses. Injection requires a pressure difference. Diffusion works with or without a pressure difference and relies on the random motion of the gas molecules.

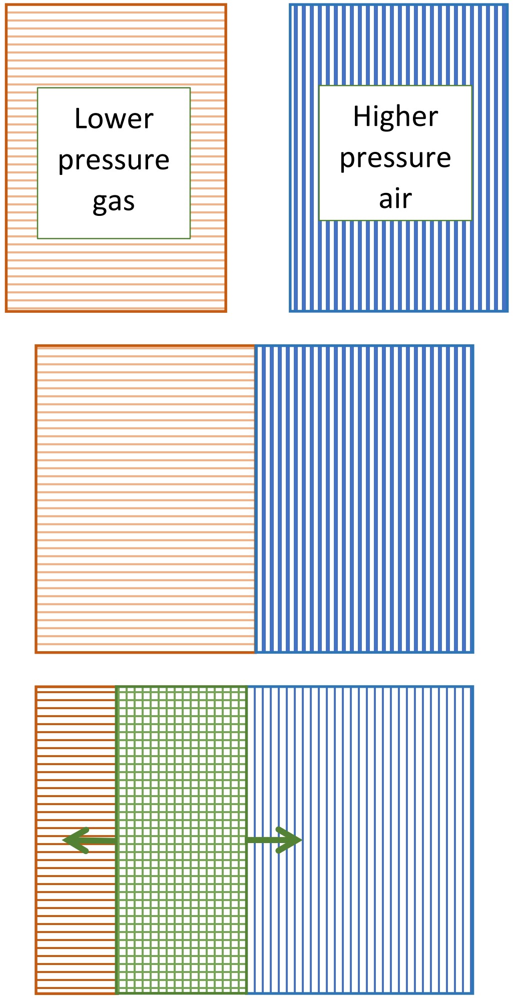
Injection



Diffusion



The actual situation: Injection + Diffusion



As far as pressure is concerned there is no difference between one square inch of surface contact and 100 square inches. The atmosphere will continually feed the process keeping the air pressure high, and buoyancy and the Venturi effect will continually keep the wood gas pressure low, no matter what the surface area is. The pressures will not equalize while the flame is burning.

Two levels of mixing:

1. Macro (turbulence and burner mixing)
2. Micro (molecule to molecule)

Turbulence vs. burner mixing