**Wonderwerk 316 TLUD-ND Descriptions and Thoughts**

The Wonderwerk 316 TLUD-ND wood stove has been tested for particulates and carbon monoxide at Aprovecho Research Center and Lawrence Berkley National Lab. It did well at both labs, burning very cleanly at all power levels, being very adjustable, and easy to use. This document looks at the inner workings of the stove, exploring its turn-down and burning techniques. Also examined are some general principles which apply to this stove and all stoves and open fires.

The turn-down technique, called the pilot flame technique, gives good but limited turn-down. The canopy device described below extends the capability of this technique, giving clean burning lower power levels. The canopy is excellent at injecting the secondary air into the wood gas, and so also gives very clean high power levels.

Several devices are placed in the gas flow path of the stove to improve its performance, these being the canopy (lower injector), upper injector, and stationary fan. My high power clean burning hypothesis is that the clean burning properties of the stove begin with the canopy device, which increases surface contact and pressure difference between the air and gas to enable injection to work. This creates the rapid and highly concentrated heat needed to crack the long chain hydrocarbon particulates into short chain flammable gasses. The cracking process may also be assisted by other phenomenon discussed below. The newly cracked flammable gasses are then injected with secondary air at the upper injector and would-be particulates are burned. The stationary blades then spin the flame gasses, not for mixing but to give them more time to finish burning before exiting the stove.

This same concentration of heat may also create oxides of nitrogen, which are constituents of smog. Testing for NOX will be important for any production stove using these principles.

What forces are operating in a wood stove?

 OXIDATION or COMBUSTION is the source of energy driving all other forces in the stove. It is a chemical reaction which produces hot gasses, leading to the buoyant force.

BUOYANT FORCE is usually called draft. This is the force that makes the gasses travel up through the stove and brings the primary and secondary air into the stove. It is a resultant of gravity where the heavier and relatively cool atmosphere pushes the lighter weight, buoyant, hot gasses within the stove upward.

VAPORIZATION PRESSURE pushes the wood gas out of the solid fuel. The solid fuel heats up until the volatiles reach a pressure that can overcome the ambient surrounding pressure, and then they vaporize and exit the solid fuel. These gasses and vapors carry away heat, and so the temperature of the fuel stabilizes at this vaporization temperature.

FLOW RESISTANCE resists the movement of gasses through the stove. If flow resistance is too high, the performance of the stove is impeded. It comes from objects in the gas flow path and friction from surfaces along which the gasses flow. Objects placed in the flame path of the Wonderwerk 316 are designed to minimize flow resistance.

The VENTURI EFFECT is always present when gasses are moving. This force can be negligible or impactful, and it can work for or against the performance of the stove. It is very subtle and seldom considered in stove design. It shows itself as pressure changes in the gasses when the flow path widens or narrows and the velocity of the gasses increases or decreases. It should be considered so that it will work for and not against the performance of the stove.

The COANDA EFFECT tends to hold a gas flowing along a surface close to the surface. It is dependent on the friction of the surface slowing the gas that is close to the surface. It is important for designing a stator fan to swirl the flame, holding the gasses to the back side of the blades such that they leave the blades at a flatter angle, giving better swirl.

**Definitions for this paper**

The **Combustor or Burner** is the upper portion of the stove where the wood gas is burned.

The **Fuel Reactor** is the lower portion of the stove where the solid fuel resides, the pyrolysis reaction takes place, wood gas is produced, and the power level is selected.

The **Stove** is the Combustor and Fuel Reactor working together.



Combustor or Burner

Fuel Reactor

Turn-down

**Definition:** TLUD-ND is a natural draft top lit up draft wood gas stove.

Power Levels

Turn-Down

**Why is the TLUD-ND wood gas stove difficult to turn down to a low power level?**

**TLUD-ND at full power shows lots of heat and strong gas and heat flows.**

**TLUD-ND turned down to a lower power level shows less overall heat and the cooling of the gasses to below ignition temperature. Turn down to ¾ power level is possible before the flame dies.**

**The pilot flame turn-down technique used in this stove consists of a few small holes (3/16” (4 to 5 mm) diameter) made ¾” (2 cm) below the secondary air entrance. The rule of thumb is one hole for each inch (2.5 cm) of fuel reactor chamber diameter evenly spaced around the chamber. These holes inject a small amount of air into the wood gas before it is diluted, not enough to cool the gas, but enough to keep small pilot flames burning. These pilot flames maintain flame presence and keep the main flame going. 1/3 power is possible.**

**The limitation of**

**the pilot flame turn-down technique is that below 1/3 power, the lift of the depleted gasses isn’t enough to hold up the ever more cooling air. The heavier air falls into the chamber and cools and extinguishes the pilot and main flames. One can watch the flame descending in the chamber.**



Here is 1/3 power, the lowest possible with this technique. The flame is on the verge of falling into the chamber.

The pilot flames are visible feeding into the main flame in all three photos.

There is no pilot flame here because there is momentarily no gas, but the other pilots will reignite it when gas returns, thus the need for multiple pilot flames.

**Pilot flames at three levels of turn-down, medium low, low and on the edge.**

**If we can keep the air from falling into the chamber, we might get more turn-down.**

**The Development of the Canopy**

**A plate with holes placed as shown will concentrate the lift of the gasses into the holes instead of dispersing it over the larger area of the chamber. Most of the air is supported by the plate, and the concentrated gasses need hold up only the air directly above the hole. This enables the reduced gasses to hold up the air.**

Such a plate with holes does give turn down to ¼ power but cannot feed air to the back side of the hole, resulting in smoke.

Top view of the plate with holes

Air

Wood gas

**Using radial slits feeds air to all of the wood gas eliminating the smoke.**

6 mm

3 mm

No molecule of gas is more than 3 mm away from a source of air.

The “legs” are formed into a V shape cross section. The V shape gives the best gas flow characteristics for both wood gas and air.

Air

]

V shape legs give lots of room for the secondary air to enter up the trough and between the gas sheets.

**Air**

V shape legs give low flow resistance for the rising gas.

**Air**

V shape legs form a nozzle shape between them to form the gas sheets.

**Wood Gas**

**Wood Gas**

Definition

Air travels along the trough and between the gas sheets. The gasses mix and ignite at and above the edges of the legs and for this paper these edges are called injection edges.

Neighboring legs form a nozzle shape between them which extrudes the gasses above the slits into sheets. This gives lots of surface contact with the air, and leaves space between for the air to enter. The gas sheets are maintained because they are at a lower pressure (because of buoyancy and the Venturi effect) than the air between them, and so the air pushing into the gas sheets maintains the sheet shape. The wood gas above the canopy occupies only the area of the extruded sheets, not filling the whole space.



The downward slope of the legs allows:

1. Longer slits then if they were flat, giving more surface contact between the gasses and so more mixing.
2. The longer slits give more open area to reduce flow resistance while keeping the slits narrow for good mixing.
3. Angled legs follow the rising of the secondary air as it heats, becomes buoyant and begins rising (details below).

Why the upward opening V shaped cross section for the legs?

1. It has a low flow resistance for the rising wood gas.

2. The legs on either side of a slit form a nozzle shape to extrude the wood gas into a thin sheet;

a. gives lots of surface contact with the air.

b. accelerates the wood gas, lowering its pressure by the Venturi effect. This increases the pressure difference between the gas and air, increasing the force pushing them together.

3. The trough and sheet shapes give lots of room for air to enter.

4.

5. The bend gives structural strength to the legs.

A canopy protects one from the rain or hot summer sun. This device looks and functions like a canopy, protecting the fuel chamber from the air falling into it, and so it is called the canopy.

**How the canopy fits into the stove**

**The canopy nestles within the flared top of the fuel reactor chamber. The tips of the legs reside just below the pilot holes. For this arrangement to work properly, no secondary air can enter below the canopy.**

**Attaching the canopy to the combustor allows it to be removed with the combustor so it does not interfere with cleaning and refueling the fuel reactor chamber.**

1. 

**Why is the top of the fuel chamber flared out?**

1. **This enables a wider canopy with longer slits giving: a. more surface contact between the gasses, and better mixing at higher power levels, and b. more open area reducing flow resistance while the slits remain narrow for better mixing**
2. **The pressure below the canopy increases to help with turn-down (see next page).**

Remember that for better turn-down we want to keep the air from falling into the fuel reactor chamber.

Comparing the tube with the sketch of the stove we see the pressure in the flared chamber increases below the canopy.

The area of the open space through the slits of the canopy adds up to ½ the area of the fuel reactor chamber, so the gas accelerates as it passes through the canopy. As described above the gas is extruded into sheets so it does not fill the large open space above the canopy, only the sheets. The space between the sheets is filled with air. The pressure of the wood gas does not go back up in the space above the canopy.

The secondary air avoids the higher pressure below the canopy and mixes with the lower pressure gas sheets above the canopy. Thus, the higher-pressure area below the canopy, being between the secondary air and the fuel chamber blocks the air from falling into the fuel chamber and extinguishing the flame at low power levels, and so the Venturi effect helps with turn-down.

Also note that the entire interior of the stove is below atmospheric pressure. The higher pessure gas is still below atmospheric pressure but above the fuel reactor chamber pressure. It is not perfect, but it helps.

These same high/low pressure areas can be used to improve high power performance. This will be described below on the high-power performance page.

**The Venturi effect and how it helps turn-down**

The Venturi effect says that as the velocity decreases in the wider tube, the pressure increases, and as the velocity increases in the narrow tube, the pressure decreases.

Lower pressure gas sheets

Higher pressure

Starting pressure

**Some things that happen when a TLUD-ND is turned down to low power**

Flow Resistance: As the stove is turned down to a lower power level the gasses are less able to overcome flow resistance. This is probably due to the higher power flame producing greater draft and the lower power flame producing less draft. Objects placed in the gas flow must be designed to allow for this lower tolerance for flow resistance at lower power levels. For the Wonderwerk 316 this includes the canopy, upper mixer, stationary fan, and pot clearance.

Room Temperature: The attainable low power simmering capability is also influenced by the ambient room temperature. A lower room temperature allows a lower attainable simmer level. Lower morning temperatures can allow simmering when higher **afternoon** temperatures keep an active boil going at the same stove turn-down setting. Fireless insulated cookers may work better in hot environments.

Heating Efficiency: The better the stove is at getting the heat into the pot, the more turn-down will be needed to simmer the food. Less heat lost means that less heat is needed which means that a lower power level is needed.

Primary air control: If the control changes the primary air flow uniformly from high to low, a 1 cm movement in the adjustment lever at high power may change the air flow by 10%, whereas at low power it may change the air flow by 90%, making low power detailed control difficult. The control device should be variable such that a 1 cm lever adjustment always changes the air flow by 10%, to allow detailed control at low power.

Oven Baking: A high power level brings the oven up to baking temperature. To hold the baking temperature over time requires considerable turn-down, or that excess heat be released from the oven, or both.

Creosote Deposits: The reduction of heat allows the fuel reactor wall to cool, allowing creosote to deposit. The wall must be lightly insulated, but not enough to stop the preheating of the secondary air. The Wonderwerk 316 stove uses a double sheet metal wall with dead air space to prevent creosote deposits.

Very Low Power Pilot Flames: At very low power levels the flame moves out to the pilot holes so that only the pilot flames are burning, there is no main flame and draft comes only from the pilots. The wood gas comes up only where the draft is at the pilot flames. The third photo on page 5 shows this beginning to happen, but it is not stable without the canopy. This is a second way that the pilot flame/canopy combination gives very low power levels.

**High Power Performance**

It turns out the canopy gives better high power performance as well as better low power performance.

TLUD-NDs have a reputation for burning dirty at high power levels. I have experimented with some ideas to address this.

A common TLUD-ND design mixes the secondary air into the wood gas below a concentrator. The concentrator constricts the flow, forcing the gas and air together in the center and adding turbulence for mixing. This combination works very well in a limited moderate power range. Its limitation is that the constriction causes a back pressure below the concentrator. As the power level increases, more wood gas is being pushed up against this constriction, so the back-pressure increases. This decreases its pressure difference with the air, decreasing the force pushing them together. It becomes harder and harder to push the secondary air into the wood gas, which results in poor mixing and dirty burning.

The wood gas accelerates through the concentrator and has a higher velocity above the concentrator. By the Venturi Effect the pressure of the gas above the concentrator decreases. This makes it easier to push the secondary air into the wood gas above the concentrator. As the power level increases more gas is pushed through the concentrator and a higher velocity and lower pressure results, making it still easier to push the secondary air into the wood gas. This would lead to cleaner burning if the gas was not concentrated into a column, making it difficult for the air to reach the fast-moving gas in the center before it exits the stove.

If a canopy type device replaces the concentrator it will increase the surface contact where mixing takes place above the constriction and minimize the depth the air must penetrate into the gas. This reduced penetration depth and increased contact surface, combined with the lower pressure, gives quick and thorough mixing and cleaner emissions at the stoves higher power levels (see next page). More work is needed here for the stoves highest power levels.

**Injection pressure** = **P**atmosphere **–** **P**wood gas

Adding secondary air below the concentrator

**High Power Performance**

Power Level vs. Wood Gas Pressure

\*High power

\*Higher pressure level

\*More wood gas

\*Less air penetration

\*Burns dirty

As the power level increases the gas pressure below the concentrator increases because more gas is backing up due to flow resistance. The injection pressure pushing the air into the wood gas decreases. This makes it more difficult to inject the air into the wood gas.

Atmospheric air pressure

Injection pressure

\*Moderate power

\*Moderate pressure level \*Moderate amount of gas

\*Good air penetration

\*Burns clean

\*High power

\*Lower pressure level

\*More wood gas velocity

\*More air penetration

\*Burns very clean

Wood gas pressure level

Injection pressure

Adding secondary air above a canopy device

\*Moderate power \*Lower pressure level \*Moderate gas velocity \*Good air penetration \*Burns very clean

Atmospheric air pressure

Wood gas pressure level

As the power level increases the gas pressure above the canopy decreases due to the Venturi effect, and the injection pressure pushing the air into the wood gas increases. This makes it easier to inject the air into the wood gas.

The Wonderwerk 316 places four objects in the flow path of the rising gasses; the canopy, the upper mixer, the stator fan, and any restriction from the cooking device like the pot gap. It is described above that the lowered flame has less ability to get through flow resistance than at high power. The flow resistance added by these four objects must be minimized to accommodate the lowest power level. Some of the choices made to this end are shown here.

**Flow Resistance**

TLUD-NDs which introduce the secondary air below a concentrator will have difficulty getting high power levels. This is the result of the flow resistance introduced by the concentrator. The Wonderwerk 316 introduces the secondary air above the constriction to avoid this problem and take advantage of the lower pressure provided by the Venturi effect.

The cooking surface design must add minimal flow resistance. An adjustable pot holder allows a pot to be raised to reduce flow resistance.

The stator blade is designed to minimize the blockage it causes, reducing flow resistance. The stator blades are aligned with the upper injector.

in tandem upper mixer 6 legs.

The number of upper mixer legs can be reduced, reducing flow resistance. Very little air is needed here to burn the newly cracked gasses.

The shape of the canopy legs reduces flow resistance in two ways.

1. The downward angle lengthens the slits increasing open area for less flow resistance.
2. The V shape is a low resistance aerodynamic shape for the rising gasses.

The widened top of the fuel reactor chamber allows a larger canopy. This allows longer slits, and more open space for less flow resistance.

**Combining of Air and Wood Gas**

**What is needed for mixing gasses?**

1. **Bring the gasses together**
	1. **Natural draft**
	2. **Forced air**
2. **Mixing and Injection**
	1. **Diffusion**
	2. **Pressure difference (injection)**
		1. **Forced air**
		2. **Buoyancy (draft)**
		3. **Venturi**
	3. **Surface contact**
		1. **Turbulence (mixing)**
		2. **Structural geometry**
3. **Time**
	1. **For mixing and injecting**
		1. **Slow**
		2. **Rapid**
	2. **For burning**

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Water

The heat of the fire forces the gas molecules further apart lowering the gas density and weight. This weight difference creates a pressure difference similar to the balloon. Unlike the balloon the flame does not move, but rather the gas flowing up through the flame is what moves.

The outside air and wood gas inside the stove are brought together when the buoyant force pushes air into the stove.

A forced air stove uses an electric fan to enhance this such that natural draft and forced air work together. Forced air may enhance or overcome natural draft, but does not eliminate it.

**Bringing the gasses together;**

**They can’t mix if they are not together**

**Buoyancy (natural draft)**

FA

ND

The weight of the water creates pressure which is equal at all points of the same depth. This pressure acts in all directions and is greater than the weight of the air-filled balloon, and so pushes it upward. This is the buoyant force.

**The movement of gasses up through the stove can be looked at like an assembly line with multiple stations. Start at the bottom.**

**A TLUD-ND assembly line**

**What is needed for mixing gasses?**

Station 1, the first function is to bring the gasses together. The buoyant force uses pressure difference to push air into the stove to meet the wood gas.

Station 5, if a combustor is used it will give the gasses more time to finish burning.

Station 4 is where the wood gas burns as it mixes with the secondary air. This is where carbon in the rising gasses becomes incandescent and visible as flame.

Station 2 is the primary air mixing with a portion of the char and wood gas, supporting primary combustion and keeping the pyrolysis front hot.

Station 3 is the hot, buoyant gases rising and separating from the solid fuel to be burned separately. This separation is characteristic of gasifying stoves.

Station 6, the hot gas gives up heat for use.

NOX

Combusted gases

Wood gas

Unburned particulates

Combusted gases

**N2**

**N2**

Heat using device

1. **Bring the gasses together**
	1. **Natural draft**
	2. **Forced air**
2. **Mix the gasses**
	1. **Diffusion**
	2. **Pressure difference (injection)**
		1. **Buoyancy (draft)**
		2. **Venturi**
		3. **Forced air**
	3. **Surface contact**
		1. **Turbulence**
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		2. **Rapid**
	2. **For burning**

**Mixing Mechanisms**

**Diffusion, Turbulence, Injection**

**Turbulence: When two gasses are mixed with turbulence, they are first brought together by the buoyant force. At this time any pressure difference is equalized. Then the gasses pass through a turbulator (any device that creates turbulence. During mixing the gasses are at the same pressure. No pressure difference pushes the gasses together, only the turbulence mixes the gasses.**

**Injection: When one gas is injected into another gas they are at different pressures and the high pressure gas pushes (injects) itself into the low pressure gas. For the TLUD-ND stove which is mixing secondary air into the wood gas, pressure difference comes from the buoyant force (draft). The Wonderwerk 316 stove has the canopy which uses the Venturi effect to reduce the wood gas pressure even further. This gives more pressure difference between the gas and air (injection pressure) helping to push them together.**

**Diffusion: Gasses can mix by diffusion when they contact each other, but there is no turbulence or pressure difference. This is when a concentrated gas spreads out by its own energy and mixes with an adjoining gas. Both gasses approach uniform concentration throughout the volume of the gasses. This very slow process cannot operate by itself in a stove. The instant the gasses mix they burn and create draft which means pressure difference, causing injection.**

**All gas stoves operate on some combination of all three. The Wonderwerk 316 with its canopy device emphasizes injection.**

 Diffusion

Pressure difference

Injection

 Turbulence

**Injection in the Stove**

**Diffusion, Draft, Venturi**

**Diffusion: The gasses diffuse into each other by their own energies at the contact surface between the gasses. Mixing is slow and weak. No flame is ever solely by diffusion, but is accompanied by pressure difference and perhaps turbulence.**

**Thoughtful combinations can give good quality mixing when coupled with increased surface contact.**

Air

Air

Gas

**Venturi effect: Higher pressure atmospheric air pushes into the lower pressure accelerated flame gas and is entrained by it.**

Air

Air

Gas

**Draft (buoyant force): Higher pressure atmospheric air pushes into lower pressure flame gas.**

**Considering the Venturi Effect**

Is it working for or against mixing?

The stove begins with the gas pressure below the air pressure due to buoyancy. This is what brings the secondary air into the stove. The larger the pressure difference, the more force pushing the gasses together

Accelerating the gas instead of the air increases the pressure difference between them by using the Venturi effect to further reduce the gas pressure. This increases the injection pressure pushing the gasses together.

As above, the air pressure is reduced, but also the gas is experiencing back pressure from the constriction. This is a double whammy, both flow resistance and the Venturi effect are hindering the pressure difference.

Air passing through the holes is accelerated and so by the Venturi effect its pressure goes down, dropping closer to the pressure of the gas. The pressure difference pushing the gasses together is reduced. The Venturi effect is hindering mixing.

The V shape gives the lowest flow resistance for the rising wood gas.

As air travels along the leg and between the flames, it heats and becomes buoyant, and may rise, pushing the flame up away from the mixer, possibly letting gas pass by unburned.

Some Types of Venturi aided air injectors

This problem can be solved by angling the mixer so it follows the rising air (as with the canopy), or by adding a top cover (as with the upper mixer).

The canopy (lower mixer) is of this type

Upper mixer is of this type

Note that the gas flow is laminar. Turbulence is not used in these mixers.

**What is needed for mixing gasses?**

1. **Bring the gasses together**
	1. **Natural draft**
	2. **Forced air**
2. **mix the gasses**
	1. **Diffusion**
	2. **Pressure difference**
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The pressure difference is equalized here

Turbulence mixing increases surface contact for more diffusion. Mixing may be lumpy. Turbulence brings the gasses together BEFORE it increases surface contact where the buoyant force pressure difference is equalized. The two gasses are at the same pressure when mixed and there is no pressure difference pushing the gasses together. For mixing, the buoyant force is mostly wasted and there is no Venturi effect present.

Canopy

The gas is extruded into sheets through the slits of the canopy. Air can mix with it from both sides all along its length, forming an inverted “V” shaped flame. This is an injection mixing method.

Area of excess air

Area of excess wood gas

**Surface contact**

**For mixing secondary air and wood gas**

**The canopy turns out to be an excellent mixer of wood gas and air. It brings the gasses together AFTER the increase in surface contact and so the pressure difference can push the gasses together. This utilizes rather than wastes the pressure difference. It uses structural geometry rather than turbulence to increase surface contact. It uses both the buoyant force and the Venturi effect to reduce gas pressure and increase the pressure difference with the air, giving more injection pressure. Mixing is even and complete. The canopy maximizes both surface contact and injection.**

Higher pressure air

Lower pressure wood gas

**What is needed for mixing gasses?**

1. **Bring the gasses together**
	1. **Natural draft**
	2. **Forced air**
2. **mix the gasses**
	1. **Diffusion**
	2. **Pressure difference**
		1. **Forced air**
		2. **Buoyancy (draft)**
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	3. **Surface contact**
		1. **Turbulence**
		2. **Structural geometry**
3. **Time**
	1. **For mixing**
		1. **Slow**
		2. **Rapid**
	2. **For burning**

**Rapid and Slow Mixing**

Slow mixing: The column of gas mixes only at its surface with the air. Mixing is driven by diffusion and injection, the pressure difference being created by the buoyant force and the Venturi effect.

Rapidly mixed flames loose less radiant heat before finishing burning, so they burn hotter.

The gas is extruded into a sheet through the slits of the canopy. Air can mix with it from both sides all along its length, forming an inverted “V” shaped flame.

Rapid mixing: The addition of Venturi low pressure and large surface contact enables rapid mixing and burning.

**Increased buoyant force (draft)**

**For Rapid mixing vs. Slow mixing**

A tall diffusion flame mixes a little at a time, slowly increasing the buoyant force so only partial draft is possible. It also radiates much of its heat away, which cools the flame and reduces draft.

Increased buoyant force (draft)

Buoyant force (draft)

Buoyant force (draft)

Rapid mixing rapidly increases to the maximum buoyant force low in the stove, giving maximum draft throughout the upper stove

Height above the flame base

Height above the flame base

Rapid Mixing

Slow Mixing

w Mixing

**Upper Mixer**

**More air is mixed in to burn the newly cracked flammable gasses.**

**Why is fast vs. slow mixing important? Stacked Mixers and the Wonderwerk 316 clean burning hypothesis**

 

Air injectors

**Hot Zone**

**Long chain hydrocarbons pass through this hot zone and are subjected to cracking into short chain flammable gases.**

**Canopy injector**

**Rapid mixing at the canopy rapidly burns the easy to burn gasses (CO, H2, and methane) to create a hot zone.**

**Rapid Mix Hot Zone**

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A Hypothesis: Assisting the Cracking of

Mixing in the Wonderwerk 316 is completed by the injection mixers before the gasses reach the stationary fan.

Wonderwerk Combustor

The smooth curve of the blade uses the Coanda Effect to hold the gasses to the back side of the blade. This gives the gasses a flatter angle of departure from the blade, and more swirl.

**Spinning the flame can enable it to finish burning before it exits the stove. This reduces the soot on the pot and the particulates in the air.**

**Adding Burn Time**

**A stationary fan blade swirls the flame giving it more burn time. This also compacts the flame keeping it hot while it is burning, giving more complete combustion. The stationary fan and created swirl are for burn time and flame (heat) concentrating only, not for mixing. The mixing has already been efficiently done by the injection/mixers.**

Long Chain Hydrocarbons

Cracking long chain hydrocarbons in a wood stove with a catalyst requires the catalyst to interact chemically with the hydrocarbon in order to lower the activation energy needed for the reaction to occur. Though efficient, the catalyst is subject to damage and has a life span. However, perhaps this cracking can be assisted rather than catalyzed. For example, hydrocarbons are very sticky and can stick to a surface, like the pot. If this happens in an active flow of hot gasses, the stuck hydrocarbons are bombard by the still flowing gasses. This bombardment combined with the heat could break long chain hydrocarbons, eventually reducing them to short chain flammable gasses. This process is not catalytic since it does not lower the energy needed for the reaction to occur. What it does is create a situation which encourages the reaction to occur but at the original energy requirement.

Placing a surface in the hot gas stream to perform this function can be combined with other functions. The Wonderwerk 316 TLUD-ND places three devices in the hot gas stream, the canopy, the upper mixer, and the stationary fan blade. Each of these has its own purpose, but also are surfaces where hydrocarbons could stick and be bombarded by the heat and gas flow. This gives the canopy a third purpose, turn-down, mixing, and a surface for cracking hydrocarbons.

The surface can be metal or ceramic. Unglazed clay is an excellent surface since it is rough with a lot of surface area to which the hydrocarbons can stick. Metal parts are smoother with less surface area, which still works but accommodates fewer hydrocarbons. The rough clay will add more flow resistance.

Think of a leaf or stick flowing in a stream. As long as it is flowing, like the leaf in the left photograph, there is no impact on it and it comes into contact only with the water close around it. If an object gets stuck and becomes stationary in the stream, like the stick in the right photograph, it gets bombarded with water pushing on it. The flow of water will bring a lot of new water into contact with the stick.

Similarly, as long as the hydrocarbon flows with the gasses it is not bombarded and comes into contact with only the gasses close around it. Only when it sticks to a surface is it bombarded, and comes into contact with lots of new gasses to react with. If the hydrocarbon sticks outside of the stream, it will not be bombarded, so it must be in the moving stream of gasses to be bombarded. This can be seen when soot is found on some parts of the objects in the gas flow.

Also note the pressure waves. The stick causes waves and troughs in the water, even in water that does not come near it. Will this cause the water molecules to interact with each other, to rub on each other? Can this also happen in the gas flow within the stove and could it contribute to cracking the hydrocarbons?

Cracking hydrocarbons is an endothermic reaction, and so requires heat to proceed. The surface must not only be in the stream of gas flow, but the gas and surface must contain a quantity and quality of heat adequate to feed the cracking process. Some stoves will not burn the gasses fast enough to concentrate the heat adequately for the reaction. There will not be enough concentrated heat, nor at a high enough temperature to enable the cracking process. A rapid burning process which concentrates the heat would be needed to assist the cracking process. A slow, tall diffusion flame cannot concentrate the heat adequately.

Placing the surface (or a catalyst) after the gasses have given off much of their heat to the cooking surface will also nullify the effect because of low heat.

Early hydrocarbon cracking techniques for oil products used both elevated heat and pressure. The pressure inside a wood stove is below atmospheric, so doesn’t that hinder the process? It is the heat that cracked the hydrocarbon chain, the pressure was there to keep the oil from evaporating. Still, there is still elevated pressure in the stove, not overall, but on a microscopic level at the points of impact. The temperature in the stove is also higher than in oil refining, helping the process.

Rapid Mixing and Burning in a TLUD-ND

vs. NOX

The Wonderwerk 316 TLUD-ND has a rapid mixing system which burns the fast burning gases very quickly in a confined space. This helps to crack hydrocarbons to reduce particulates. A high concentration of heat is also what is needed to create NOX.  No tests have been done to determine if this is occurring in this stove. The only clue is that in spite of the low particulate production of the stove, which should produce white test filters, the filters are tinted slightly brown. Nitrogen dioxide is a brown liquid below 70 F. It is possible that the brown tint is from condensed NO2. This could mean that NO would be 19 times greater than the NO2 since the usual combustion ratio is 93 (NO) to 5 (NO2). This would make the stove a smog producer, although not on the level of an automobile.

Could the equipment in a California (California because the smog restrictions are very strong) smog station give an accurate measure if such is true? Should I get the stove a smog test?

**Stove Test Results**

**Using 3.5 kw for high power and 1.6 kw for low power**

