

TLUD Handbook: Draft 1 for Discussion

Revision 1.2 --- 2008-01-25

Revision 1.3 --- 2010-02-20

This document is an incomplete draft dealing only through 2007, and is already out of date. It is released as a “starting point” document to stimulate further discussion, updates, and easy-access to background for persons new to Top-Lit UpDraft pyrolytic gasification.

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1. Introduction

This *TLUD Handbook: Draft for Discussion* is a “work in progress.” Rather than delay its release any longer, it is in rough draft form. Therefore, expect it to have many Revisions (updates). Please do not utilize outdated releases.

Many parts of this handbook will overlap, and some things will be repeated. However, through this repetition, you will see the evolution of the technology in the various items presented.

To get started, watch this video of a TLUD stove in action:

<http://www.youtube.com/watch?v=SaeanoWZE7E>

The first 30 seconds shows an overview and was submitted to Google's "Project 10 to the 100th" contest. The rest (2:50) shows the processes and issues in more detail.

Dr. Thomas B. Reed is the recognized originator (in 1985) of what is now called Top-Lit UpDraft gasification, shortened to "TLUD". However, in 2008 we became aware of the totally independent original work of Paal Wendelbo, a Norwegian working in Uganda in the 1990s. Reed and Wendelbo are the independent co-originators. Others who have done significant work with the TLUDs up through 2007 are the "Pyroneers."

For anyone just getting started with TLUD cookstoves, a concise set of key references includes the following:

"*Micro-Gasification: What it is and why it works*" by Anderson, Reed, and Wever (2007), at: <http://www.hedon.info/docs/BP53-Anderson-14.pdf>

An overview of gasification (2004) is at: <http://bioenergylists.org/stovesdoc/Anderson/GasifierLAMNET.pdf> .

The exceptionally clean combustion of TLUD stoves (2009) is presented at: <http://www.bioenergylists.org/andersontludcopm> .

Instructions for making the Champion TLUD (2009) are at <http://www.bioenergylists.org/andersontludconstruction>

In simplified terms, the burning of dry biomass involves three major chemical reactions: The most visible one is the "combustion" (full or incomplete) of the combustible gases created by the other two reactions. Combustion requires "secondary air" for the necessary oxygen, and gives the visible flames. The other conspicuous reaction is the chemical transformation ("pyrolysis" and "carbonization") caused by heat (with or without oxygen), resulting in combustible gases and the creation of charcoal. The least visible is the oxidation ("primary air" is required) of the carbon ("char-gasification") to create carbon monoxide, which is combustible if kept concentrated and hot. Ash is the non-combustible residue after char-gasification.

These three processes occur nearly simultaneously in regular fires, making them difficult to see or to control individually. The simultaneous entry of the primary and secondary air is the major reason why burning wood and other biomass in traditional/typical stoves is incomplete, causing smoke and serious health problems.

But when the gases are generated but not burned immediately, the gasification processes (pyrolysis and char gasification) are more easily understood, seen, and controlled. This separation of gasification from combustion (including the separate entry of the primary and secondary air) is the key distinguishing characteristic of "gasifiers," and is the main reason they can be so clean burning, even in small cookstoves.

Commercially viable gasifiers have long been understood and used in large industry and even in transportation (over one million vehicles during WWII), but not for small applications such as a household stove.

In 1985 on a trip to South Africa, gasification expert Dr. Thomas B. Reed awoke one night thinking of a very small gasifier for the domestic stove needs of impoverished people. For ten years he worked to develop what is now called the TLUD (Top-Lit Up -Draft) natural draft gasifier stove. In 1995 Dr. Ronal Larson joined the effort with a focus on the gasifier's capacity for producing charcoal as a valuable by-product in a household stove. After testing and publications, but no real success for applications, they stopped that work in 1996. However, in 1998 Dr. Reed began work on a smaller, forced convection model with a fan with the intention to make a stove for the affluent North American camper market. He has successfully produced the "WoodGas CampStove" for marketing in 2003 and can produce impressive heat for sustained periods. Some modifications are necessary for applications in developing countries.

Independently and virtually unknown until 2008, Norwegian Paal Wendelbo successfully developed the “Peko Pe” natural draft TLUD cookstove in Uganda in the 1990s.

In 2001, Dr. Reed lit his early prototype forced-air gasifier stove on a kitchen table for Dr. Paul S. Anderson and two others to see. Sufficiently impressed, Dr. Anderson started experimenting, studied Reed’s original TLUD gasifier, learned much from the “Stoves Listserv,” and subsequently devised numerous modifications that resulted in the “Champion” TLUD model in 2005. There are important similarities between Anderson’s Champion and Wendelbo’s Peko Pe that result in successful natural draft Top-Lit UpDraft stoves (TLUD-ND).

2. Terminology important to TLUD gasification issues

The term “TLUD” originated in 2005, so you will not find it in the earlier writings. “Top-Lit UpDraft” was used in 2003. That became the “TLUD” which is hard to pronounce, and finally in August 2005 at the Stove Camp, David Penise first pronounced the name “T-LUD”, as in “tee-lud”, or as in the name of the T. Rex dinosaur. Some people write the name without the hyphen, as in TLUD, but T-LUD is more likely to encourage a better pronunciation.

The term “inverted downdraft” (IDD) was used for many years by Tom Reed, the acknowledged originator of *controlled* top-lit updraft (TLUD) gasification. While technically accurate, the concept of an inverted downdraft was difficult to explain.

Both TLUD and IDD (and their corresponding words) refer to a method of combustion that is essentially pyrolytic gasification of dry biomass, followed by the combustion of those gases, with a co-product of charcoal that can be saved or combusted. TLUD and IDD are public domain terms that describe a method or process. They are not the names of a specific stove or device. There can be many TLUD-style devices.

The term “stove” refers to an object or structure in which heat is created and used for cooking. Therefore, a TLUD stove is one that utilizes the TLUD gasification technology in a stove structure. Likewise, there can be TLUD water heaters, TLUD fruit driers, and other application devices in which the TLUD technology is used in the creation of heat.

The name “Juntos” is the trademark of Paul Anderson’s stoves.

The name “Champion” has been taken as a trademark name for the specific TLUD gasifier stove that won the award for the cleanest combustion at the Stove Camp of 2005.

Additional terms will be used and explained in other sections of this handbook.

3. Early writings (annotated bibliography)

This section of the Handbook will eventually become the bibliography. But at this point we want to call attention to existing materials so that we can assume the readers to have that knowledge when dealing with later topics.

Many of these items are available on the Internet, with many at these two sites:

www.repp.org/discussiongroups/resources/stoves

www.woodgas.com

Our order of presentation here is under revision and does not include items added in 2008 - 2010. The presentation below is directly from the [stoves.repp.org](http://www.stoves.repp.org) Internet site as organized by each contributor’s name. Items that do not relate to TLUD gasification have been deleted.

Note that some articles or presentations were done by teams, so there are some repeat citations.

<http://www.repp.org/discussiongroups/resources/stoves/contributions.html>

A. Paul S. Anderson

Juntos

Illinois and Mocambique

- [Rice Husk Gas Stove Handbook](#), Alexis T Belonio, Appropriate Technology Center, Iloilo City, Philippines
 - [Preface by Paul S. Anderson](#), January 2006
- [Biomass Gasification: Clean Residential Stoves, Commercial Power Generation, and Global Impacts](#), 8-10 Nov 2004, Viña del Mar, Chile, Paul S. Anderson (Ph.D.) and Thomas B. Reed (Ph.D.)
- [A Bibliography of Hayboxes or Fireless Cookers](#), Paul Anderson, September 2003
- [Juntos Gasifier Stove](#) (July 2003)
- [Large Juntos Stove](#) (Nov 2002)
- [Juntos Stove Testing](#) (Feb 21, 2002)
- [Juntos Stove](#), Modified Rocket Stove (Jan 31, 2002)

Additional items by Anderson are in the ETHOS Conference Proceedings
ETHOS == Engineers in Technical and Humanitarian Opportunities of Service
<http://www.vrac.iastate.edu/ethos/index.php>

2004: [Gasification: A Process Common to All Biomass Stoves](#) -- Thomas B. Reed, Agua Das, Paul S. Anderson

2005: [Three Short Reports on Successful Stove Progress](#) -- Paul Anderson

2005: [The Science of Biomass Stoves](#) -- Thomas Reed

2006: [Top-Lit Updraft \(T-LUD\) Gasification Advances of 2005](#) -- Paul S. Anderson

2007: [Progress Report on Small TLUD Gasifier Devices in 2006](#) -- Paul S. Anderson

2008: [TLUD Gasifier Cookstove Developments in 2007](#) -- Paul S. Anderson

2009: [Top-Lit UpDraft \(TLUD\) Gasifier Highlights of 2008: Designs, Low Emissions, and Applications](#) -- Paul S. Anderson

B. Tom Reed

Biomass Energy Foundation

Golden, Colorado

- [Biomass Gasification: Clean Residential Stoves, Commercial Power Generation, and Global Impacts](#) 8-10 Nov 2004, Viña del Mar, Chile, Paul S. Anderson (Ph.D.) and Thomas B. Reed (Ph.D.)
- [Biomass Energy Foundation](#)
- [Woodgas Stove Flame](#), Tom Reed (February 2, 2002)
- Two Papers on The Turbo Stove, Tom Reed (July 31, 1999)
 - [The New Turbo Wood-Gas Stove](#)
 - [The "Turbo" Wood-Gas Stove](#)
- [Drawing of the IDD Wood Gas Stove](#)
- [A Wood-Gas Stove for Developing Countries by Tom Reed and Ronal Larson](#)
- [Background on the "Inverted Downdraft Gasifier" by Tom Reed](#)

C. Ron Larson

Colorado

- [Ceramic Charcoal Making Cookstove](#) Richard Boyt and Ron Larson June 2003
- [A Wood-Gas Stove for Developing Countries](#) by Tom Reed and Ronal Larson

D. Alex English

Canada

- [Two Days at the Appropriate Rural Technology Institute Field Research Station in Phaltan, India](#) Working with Hemant Mahajan (ARTI Engineer, with the white cap) to demonstrate charcoal production using Top-Down pyrolysis and off-gas combustion. (Nov 28-29, 2000)
- [The Bigtop Pyrolyser Temperature Profile](#), (Oct 20, 2000)
- [The Bigtop 50 kilowatt wood pellet gasifier / charcoal maker](#) (Sept 27, 2000)
- [Pyrolyser with Horizontal Burner](#) (March 24, 2000)
- [Clean combustion of pyrolysis gasses while making charcoal with wood pellets.](#) (March 25/99)
- [Summary of one afternoon of tests done on a down draft wood boiler.](#) (March 25/99)
- [Drawing and Pictures of the arrangement used to turn a drum full of dry wood into charcoal while burning off the noxious gasses.](#) (July 12/ 98)
- [Flaring Gasses While Making Charcoal](#), (July 3/98)
- Fruit Drier Heat Exchanger
- [Testing Stoves With a Vent Hood](#) (Dec 18/97)
- [Alex English's University Test Burner](#) (Oct 14/97)
- [Venturi Gasifier Test.](#) (Sept 18/97)
- [The Curvacious Charcoal Making Wood Gas Burning Stove](#) (Latest test, Sept 11/97)
- [Alex English's Latest Experiment](#) (Aug 1/97)
- [Picture of the swirl inducing add on for the venturi shown above](#)
- [Cut away view of swirl inducing add on](#)
- [Drawing and discription of the venturi burner.](#)

E. Elsen Karstad

Chardust Ltd.

Nairobi, Kenya

- [The World's Formost Authority on the One Can Stoves](#) (July2/98)
- [Pictures of Elsen Karstad's Sawdust Carbonizing Experiments.](#) (March 31/98)
- [Pictures of Elsen Karstads Stove](#) (Oct 31/97)
- [Elsen Karstad's Charcoal Making Wood Gas Cooking Stove](#) (Oct 2/97)
- [Elsen Karstad's Charcoal Making Wood Gas Cooking Stove](#) (Sept 19/97)
- [Pictures of Elsen Karstad's Version of the Two Can Charcoal Making Stove](#)

F. Alexis Belonio

Philippines

G. Paal Wendelbo

Norway

And there are more from the stoves.repp.org website. This list is not complete.

4. History of TLUD gasification and development

A short history (which we plan to revise soon) is found on the last page of

- [Biomass Gasification: Clean Residential Stoves, Commercial Power Generation, and Global Impacts](#) 8-10 Nov 2004, Viña del Mar, Chile, Paul S. Anderson (Ph.D.) and Thomas B. Reed (Ph.D.)

See also Tom Reed's statement from 1995:

- [Background on the "Inverted Downdraft Gasifier" by Tom Reed](#)

5. Theory of TLUD gasification

Much to be re-written here. Some basics are in:

- [A Wood-Gas Stove for Developing Countries by Tom Reed and Ronal Larson](#)

6. Construction issues regarding TLUD gasification

Various items cited above have diagrams that show a wide range of constructions of TLUD gasification devices. Each has its advantages and disadvantages. In agreement with the previously discussed theory, there are several physical components to a TLUD gasifier. They are probably best described from the bottom to the top vertical order:

A. The fuel container:

1. Typically a vertical cylinder that is taller than its diameter, perhaps even several times taller than its diameter.

2. Primary air must be able to enter at or near the bottom of the column of fuel, so the fuel container will typically have a grate (or perforated bottom) and some form of support that allows for air to reach the inlets.

3. Major problem: After the pyrolysis of the biomass fuel has occurred, the fuel container will have a substantial amount of char, some ash, and sometimes some non-pyrolyzed fuel that will need to be removed. Options are:

- a. to turn the entire stove upside down (as in the Reed's WoodGas CampStove)
- b. to remove just the fuel container so that it can be turned upside down (as in Anderson's Champion stove)
- c. to have a grate or bottom that can be opened like a trap door so that the charcoal, etc, can fall downward into some receptacle (as in Belonio's Rice Husk Gas Stove).
- d. to have something unusual (like a vacuum suction device) to extract hot char (no known devices of this type.)

B. Mechanism for entry of secondary air:

1. Simply stated, this constitutes holes or gaps. The trick is in how to accomplish their placement.

2. Many variables can become important, including size of the opening(s), position of the openings, pre-heating of the secondary air, protection from wind and air currents, cost, and the major issue of having forced secondary air versus natural draft. Some discussion of this is found on pages 5 to 8 of:

- [Biomass Gasification: Clean Residential Stoves, Commercial Power Generation, and Global Impacts](#) 8-10 Nov 2004, Viña del Mar, Chile, Paul S. Anderson (Ph.D.) and Thomas B. Reed (Ph.D.)

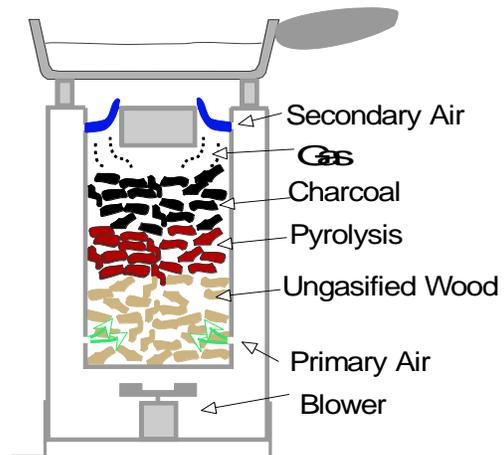
C. Mechanism(s) for assurance of draft:

1. The discussions of forced-draft devices and natural-draft devices are quite separate. Mechanically driven (physical or electrical power) devices such as fans and blowers, are fundamentally different from the chimney (thermal-difference power) devices that have different diameters and lengths.

2. Note: The Reed WoodGas CampStove has fan-forcing of both the primary and secondary air, the Anderson Champion stove is natural draft for both types of air, and the Belonio Rice Husk Gas Stove has forced primary air but no draft of the secondary air, that is, the quality of those gases (with high flame speeds) means they burn upon exit from the gasifier.

D. Sometimes these components impact each other: The stove structure (legs, cooking surface, insulation, chimney position, etc.) can impact one or more of the three components. But, in essence, only A, B, and C above are required to have a successful TLUD gasifier.

The following pages from November 2004 give construction instructions concerning one type of TLUD unit utilizing forced air.



Basics of the Reed-Anderson Small Gasifier Stove Designs (November 2004)

A. With Forced Air

There are only three main components to the designs of the WoodGas/Juntos small gasifiers with forced air. Their principal characteristics are listed below, but many variations are possible. We present the three components of the *gasifier-combustion units*. We do not address here the wide varieties of devices for the use of the heat, the most common of which are a “stove” structure (legs, chimney, plancha, etc.), pot, oven, drier, and room heater. The gasifier can work with a full variety of applications of heat.

1. The “combustion unit” or “fuel unit” (made from two cylindrical “cans”)

1.a. Fuel chamber:

This cylindrical container 10 cm (4 inches) in diameter and 6 to 8 inches tall, with closed bottom and open top, has twelve primary-air holes of $7/64^{\text{th}}$ inch diameter (almost $1/8^{\text{th}}$ inch) evenly spaced around the can about 1 cm (half inch) above the bottom of the can. It also has thirty-two secondary-air holes of $11/64^{\text{th}}$ inch diameter (almost $3/16^{\text{th}}$ inch) evenly spaced around the can about 2.5 cm (1 inch) down from the top. Although tin cans will suffice, better steel helps withstand the temperatures of pyrolysis (approx. 400 deg. C.) and of burning charcoal (over 900 deg. C). This chamber is the most critical part of the small gasifiers because a one-to-five ratio of primary to secondary air (allowing for resistance by the fuel) is extremely important.

1.b. Outer cylinder for air control:

This cylindrical container is 15 cm (6 inches) in diameter with the same or slightly less height as the fuel chamber, with an open bottom, and a sealed top, through which the fuel chamber is inserted approximately 1.5 cm (half inch) and attached using heat-tolerant rivets, screws, spot-welds, clamps, etc. (Avoid aluminum and plastic fasteners). The attachment of a heat-tolerant handle on this outer cylinder is highly recommended but is not considered to be a separate piece.

2. Air base

The above described combustion unit is to be placed on top of the air base, a component that will direct the forced air upward to enter the primary and secondary air holes. Gravity holds the combustion unit on top of a flat-topped air base, preventing major leakage of the air. The air base must be sufficiently open on the top to allow the passage of the forced air upward into the combustion unit, sufficiently sealed on the sides and bottom to prevent the escape of the forced air, and with provision of access (side or bottom) for the entry of the forced air. Note that the device to provide the forced air (a fan or a blower) could be incorporated into the air base or could be external to the air base.

3. Fan or blower

For each kg of fuel burned, approximately six cubic meters (6 m^3) of air needs to be delivered with sufficient force and control. Surplus airflow is not a crucial concern because one blower could service several air bases or have controls as simple as a baffle to reduce the flow. If available, electricity (via any grid, battery, or photo-voltaic device) is the simplest power for using fans and blowers. A typical hair-dryer blower would be far too much power. Small one-watt DC electric motors can be sufficient power for a fan if properly ducted via the air base. A small battery (perhaps recharged by solar photo-voltaic cells or at a recharge shop) can provide hours of forced air, depending on the configuration of the air base. Peltier effect thermoelectric devices (TED/TEM) could be used, being powered by the heat of the stove itself.

Manual power can be used but would require the person to be present continually or also require a storage mechanism. A wind-up spring mechanism is being considered. Stirling engines or

steam ejectors also could be adapted. Households and societies can choose from several acceptable options to obtain the forced air.

Note that Reed's "WoodGas CampStove" has the air base and the fan built into the lower part of the outer cylinder. This has advantages and disadvantages depending on the user's intentions. It also has four "pot supports" on top, and therefore is a totally self-contained stove.

B. For Natural Draft

All stoves depend on acceptable airflow. The only two sources are forced or natural. Natural draft is basically air movement caused by the tendency of hot air to rise. Chimneys are the main instruments to strengthen natural draft.

In Anderson's Juntos designs for natural draft small gasifiers, the combustion unit and the air base appear to be similar to those described above, but the positions and sizes of the primary and secondary air holes are importantly altered. The biggest difference in the natural draft gasifiers is that instead of the fan or blower, a chimney configuration is needed. A chimney between the combustion chamber and the cooking area (thereby providing space and time for complete combustion of the gases), is an "internal chimney." When it is beyond the cooking area, it is a regular chimney or a post-point-of-heat-use chimney (or an "exit chimney"). Because of several design variables that must be considered for proper operation, we do not present detailed descriptions and discussions of the Juntos natural draft small gasifiers in [the November 2004 LAMNET] presentation/ publication. Interested parties should contact Dr. Anderson directly.

Building a Champion stove. [Note: for use at elevations below 3300 feet (1000 meters)]

[[A more up-to-date explanation is provided at:

<http://bioenergylists.org/andersontludconstruction>]]

Since November 2004, much has changed and become clearer. Especially important is the finalization of the design for the Champion stove that won the contest for clean emissions at the August 2005 Stove Camp.

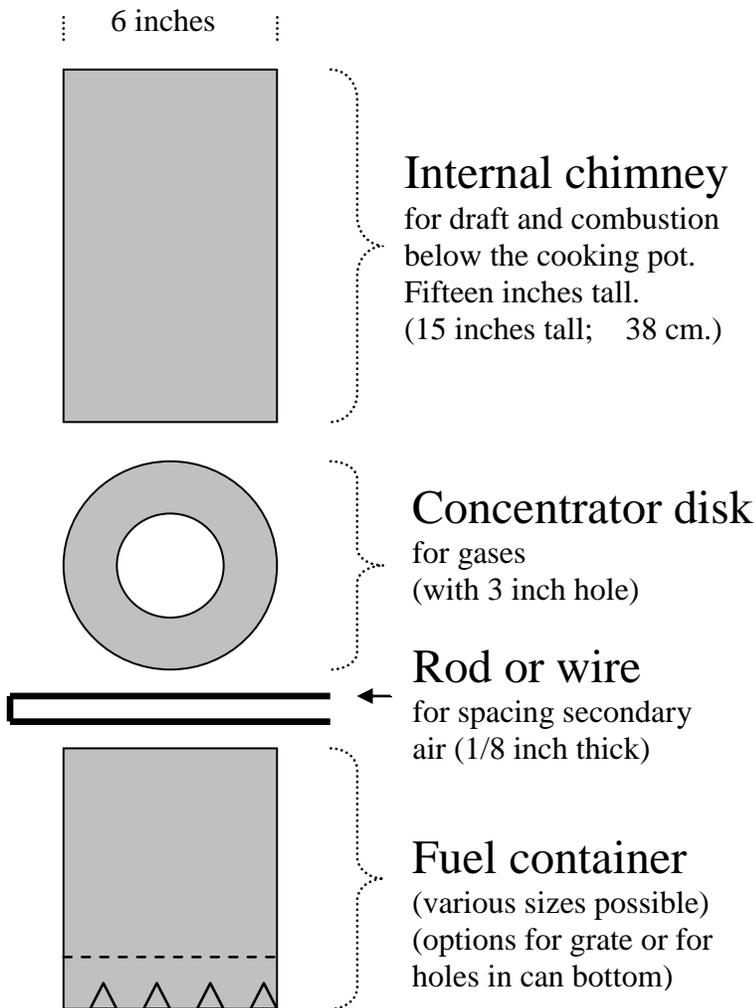
As stated earlier, the combustion technology (in this case the TLUD gasification) is distinct from (but related to) the stove structure (such as what is known as the Champion stove). Therefore, first we present the TLUD gasification components as they are found in the Champion stove, and we explain the specification code:

Specification code: Two very important measurements are the diameter and the height of the internal chimney. In the tested Champion stove, those measurements are 6 inches and 15 inches, so it becomes a model number "Champion 6-15". Not all combinations of measurements have been tried, but we are quite sure that for a residential cookstove, diameters of 8 inches (or more) and 4 inches (or less) would be as successful as the 6-inch diameter internal chimney. Similarly, heights of 18 inches could make the final stove too tall, and heights of 12 inches or less risk having insufficient draft. In summary, the 6-15 size may have some variation, but not too much.

Internal chimney: Use 6 inch diameter black stove pipe from a hardware store. The length of 24 inches can be cut into a 15 inch internal chimney and the remainder becomes a 9 inch tall fuel container. Do not use the galvanized (silver color) duct pipe because the galvanization might be burned off, resulting in toxic gases. Also, the galvanized duct is of thinner gauge steel.

The concentrator disk with its 3 inch hole in the middle could be a 6-inch diameter disk that is inserted a short distance (about a half inch or one cm) into the bottom of the internal chimney. What is important is that the up-flowing gases are concentrated and are forced to move through the hole with greater velocity. (A 2 inch hole is too small and a 4 inch hole is too large.)

(To accomplish the same result, the concentrator could actually be a large size (such as a 7 x 7 inch square) and the internal chimney could sit on top of it. The combustion would be fine, but the construction of a complete and functional stove would be more difficult.)



The 1/8th inch diameter spacer rod is to be 1) under the horizontal concentrator disk, and 2) on top of the upper lip of the fuel container. This gap has proven to be correct for the Champion 6-15 stove as tested thus far. The two arms of the rod or wire should be parallel and separated slightly more than the 3 inch diameter of the hole in the concentrator disk. The use of one rod that is bent into a “U” shape is convenient, but two separate rods would work equally well.

The fuel container may be fabricated in a variety of ways that are discussed later. For the TLUD gasification method to function, what is needed is an open-top container that at the bottom is able to hold the fuel in place and still allow the primary air to enter upward through the fuel. For a natural draft TLUD gasifier, it is better to have too many holes or opening in the bottom than to have too few because the functioning of the device is dependent on the pulling of the primary air upward via only the negative pressure created in the internal chimney.

For purposes of testing the TLUD combustion principles or for testing different types of fuels, you do not need to have a functional stove, meaning you do not need to have the stove structure of legs, supports, etc. Instead, in a safe location (remember to protect the floor from the heat), you can do the following:

1. fill the fuel container with the dry chunky biomass,
2. light it on top (see separate instructions),
3. place the doubled spacer rod over the top rim of the fuel container,
4. lay the concentrator disk over the rods, and
- 5/ stand the internal chimney on top of the disk.

Be careful because the above arrangement is not stable, but the TLUD operation will be clearly seen.

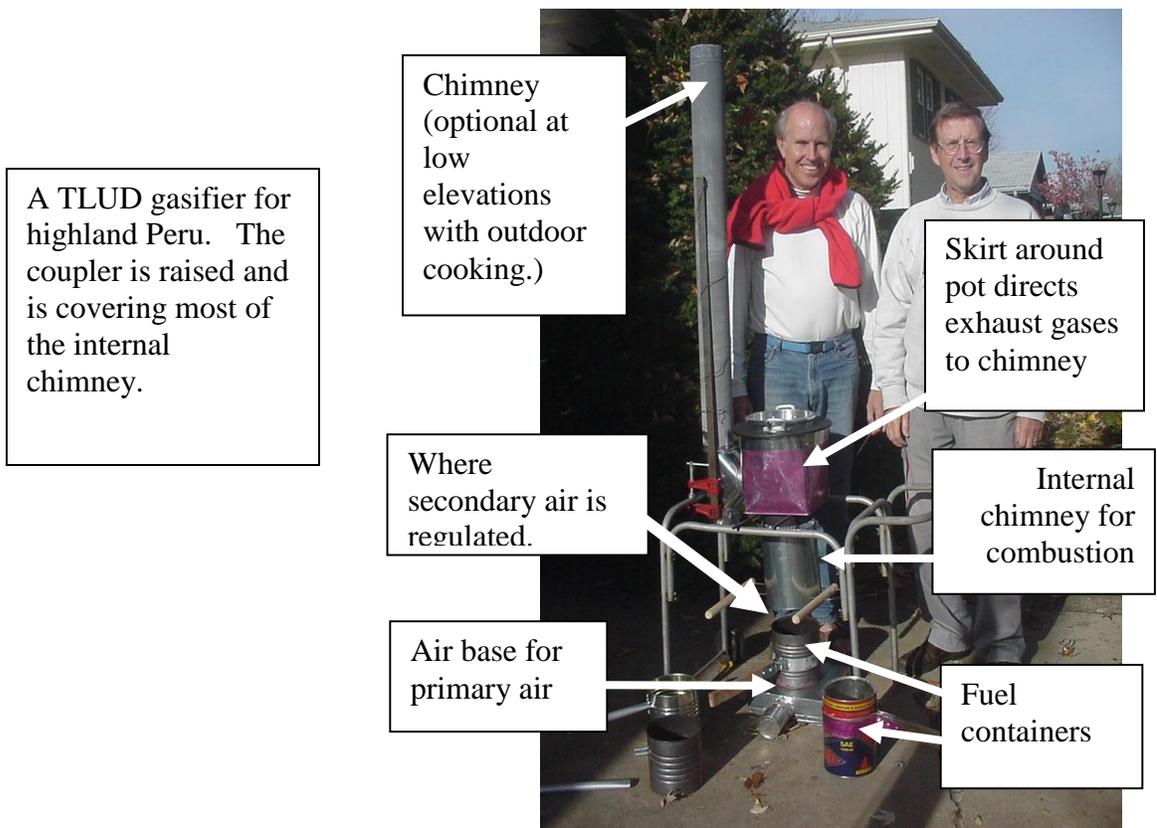
Please note that you can easily change any of the components' dimensions or materials in subsequent test firings.

Constructing the stove structure with a functional TLUD gasifier included.

Making the stove stand up:

The top of the stove must be able to support a cooking pot, and that means some support structure is essential for the top of the stove. The top may be held up either from the sides, or from below.

a. Support from the sides usually involves two parallel rods (such as 3/8 inch diameter rebar) that attach (via several ways) near the top of the internal chimney and extend sideways long enough to find support in the walls of the kitchen or onto "legs" of some sort. Basically, the internal chimney is suspended below a stable stove top. This allows the placement and changing of the fuel canister without displacing or disturbing the cooking pot.



b. Support from below is typically like stacking two boxes or cans on top of each other, with the upper one holding the pot on top and the internal chimney inside, while the bottom one has one side cut open to allow the placement and changing of the fuel container.



The disk in the bottom rises under the fuel canister, and is held in the raised position by the red stick on the outside. Note the metal controller of the primary flow.

Connecting (and disconnecting) the fuel canister from the internal chimney.

Because the secondary air enters where the fuel canister and the internal chimney meet, some leeway is allowed for leaking of air at the area of union. But too much air passage will favor the entry of secondary air (diluting the heat) and reduce the drafting of essential primary air upward through the fuel container. Therefore, a reasonably efficient connector method is essential.

Two realistic connector methods are known:

- a. Raise the fuel canister up to the spacer rods, or
- b. Have a sliding connector (a coupler) on the internal chimney. The coupler would include the concentrator disk and the spacer rods (with handles able to be connected to the ends of the spacer rods).

Note: One construction method for attaching the spacer rods and constrictor disk to the internal chimney is to drill or punch four holes in the bottom centimeter of the side of the internal chimney so that the spacer rods fit through those holes, and then the concentrator disk sits upon that pair of rods. The complication of this method is that the fuel container should have an upper

diameter of only five inches. Other notes about how to make the connection (and disconnection) of the fuel container and the internal chimney will be forthcoming.



Photos of the original Champion stove that won the clean combustion contest in 2005. This unit was built in Cochabamba, Bolivia, for operation at over 2000 meters elevation.



7. Construction of stoves (structures) that use TLUD gasification

7.1. The Champion stove

7.2. Un-named stoves

8. Operating TLUD Gasifier Stoves

A. Fuel: The fuel must be a “chunky” dry biomass, permitting airflow through the fuel bed. This airflow can also relate to the power of the fan/blower. For simplicity, think of the typical fuel as being irregularly shaped wood chips with dimensions of 0.5 x 1 x 2 cm, plus or minus half of each dimension. Standard pellets for pellet stoves are about as small as would be acceptable. Sawdust *does not* work because it settles too compactly. Loose big sticks *do not* work because there is too much space between them. Basically, the user should be able to gather up by handfuls or with a small scoop the fuel to load into the fuel chamber. The fuel level should be at least one cm below the level of the secondary air holes.

B. Starter material: It is very important to light the fuel on the *top only*. Because we are top-lighting, we need to have reasonable immediate combustion of the upper layer of the fuel. For this, we use a “starter” material (tinder) that will ignite easily with one match and stay lit for a minute or two. Simple paper is *not* acceptable because it burns out too quickly. The simplest way to obtain starter material is to take some of the basic fuel (described above) and coat it with a *small* amount of any of the following liquids: kerosene/paraffin, citronella oil, flammable alcohol, diesel fuel, or other “reasonable” flammable liquids. Some pine residues could be acceptable. (*Do not* use gasoline, and *do not* add a liquid starter directly onto fuel already in the combustion chamber because a drip can provide a path for the fire to reach the bottom, causing too much gas to be released in too short a time to be useful.) Place a small amount of the starter (equal to 5 to 10 pieces of the typical wood chips described above) across the top of the fuel.

C. Ignition: Ignite the starter fuel with a match to have flame in all areas of the top of the fuel chamber. Allow it to burn for a few seconds, and then place the fuel canister underneath the internal chimney. With a forced air unit, simply turn on the forced air in a *low* amount. When the flames stabilize in about a minute, you can increase the amount of forced air. If you observe any sooty flames at the beginning, it is probably because of excess starter material. If the flame is not uniform over the top of the fuel chamber at the level of the secondary air holes, you probably need to follow more closely the instructions about the level of the fuel or the ignition of the flame over the entire top of the fuel. With a little practice you will be able to avoid these conditions.

D. Operation during the burn: The fire will continue for 10 to 45 minutes depending on the amount and type of fuel and the amount of forced air. The “pyrolysis front” is progressing downward through the fuel supply at a rate controlled by the amount of primary air entering via the bottom air holes. To increase or decrease the heat being produced, you can make adjustments to the amount of primary air entering during this time. But try to avoid sudden shifts. For example, an excessive gust of air (internal or external to the stove) can extinguish the flame at the secondary air holes. That will result in voluminous smoke (pyrolysis gases which are the fuel for the secondary combustion). A single match should be able to re-ignite the gases, but there can be other complications that are left for more detailed discussions elsewhere. Also, to extend the time of the burn, *small* amounts (about 1/4 handful maximum) of the dry biomass can be added on top of the fuel during the pyrolysis stage of the burning.

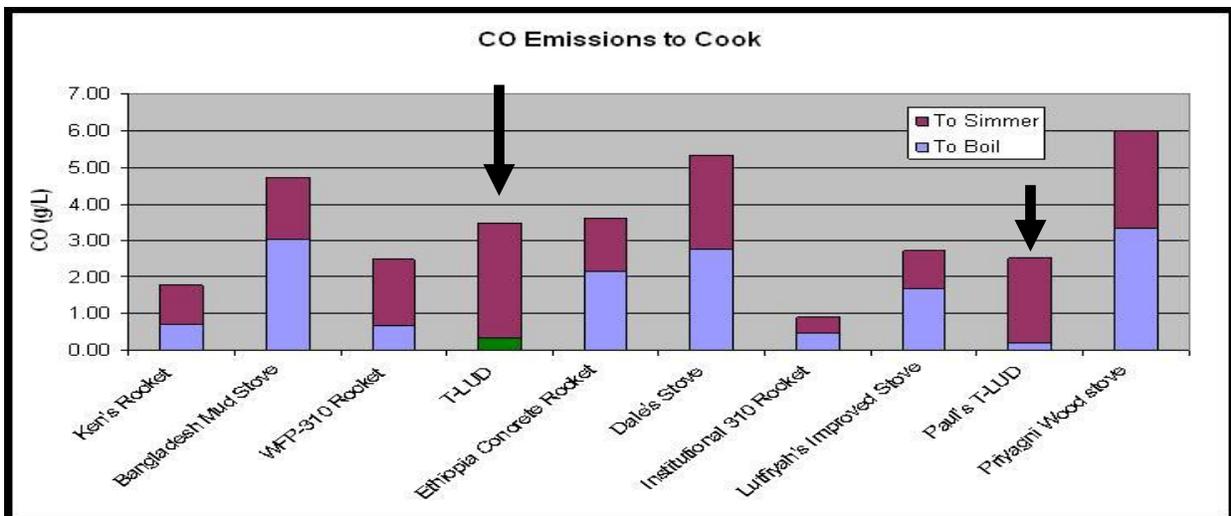
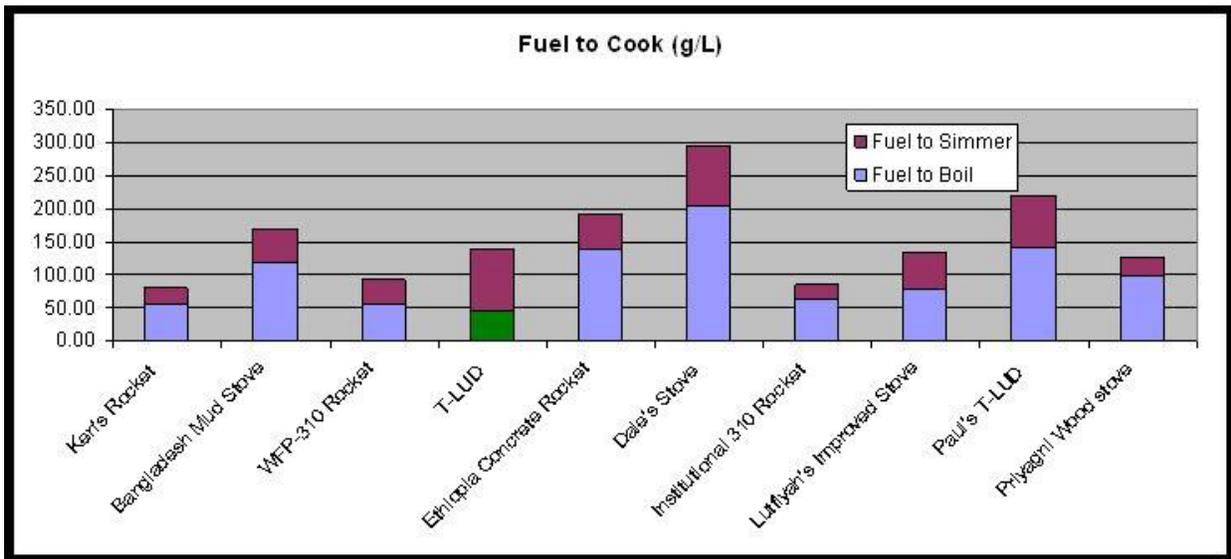
E. Conclusion of the burn: When all goes well (as it usually does), the pyrolysis (smoke-making) process proceeds all the way down through the fuel, resulting in only charcoal remaining in the fuel chamber. Then the primary air is blowing directly onto the hot char, making

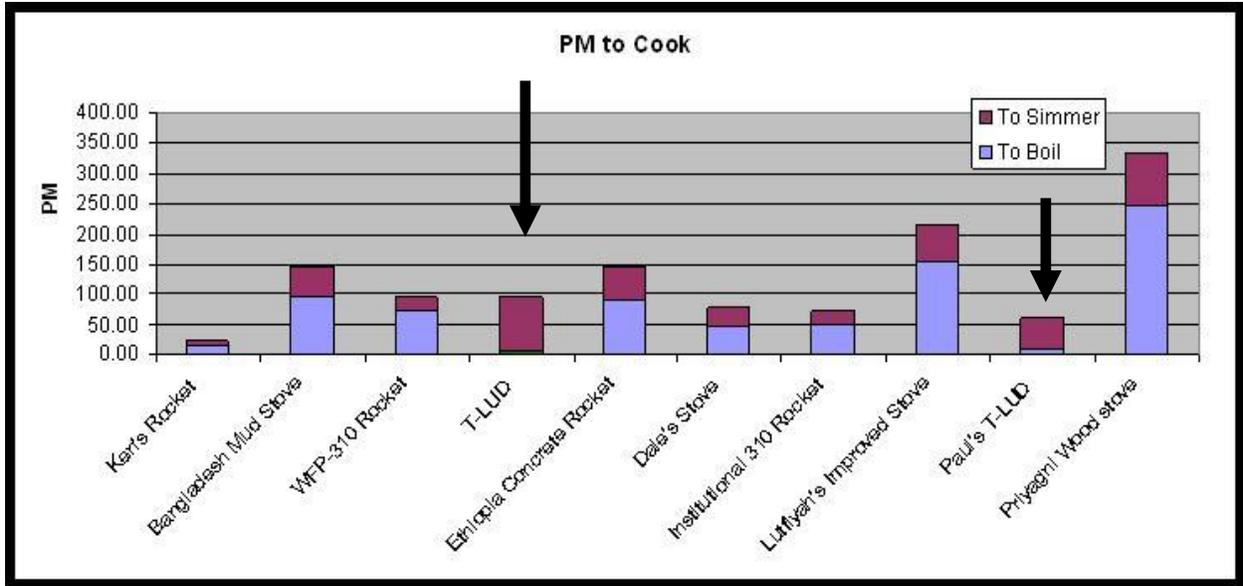
a much hotter but much smaller fire of red-glowing char at the bottom of the charcoal bed. If this amount of heat is sufficient for the cooking needs (such as simmering), simply let it burn until virtually all the char is consumed. Alternatively, the user can remove the combustion unit and dump the hot char into a “snuffer can” that is simply a metal can with a tight-fitting lid. The char will be extinguished in about 5 minutes. [To continue the cooking, a second combustion unit could have been loaded with fuel and starter material, then lit just before removing the first combustion unit, and placed onto the air base.]

One of the most sensitive times of the operation is when the pyrolysis is almost complete. Sometimes there is still some pyrolysis occurring but insufficient gases to maintain the secondary combustion. That means smoke is released. Usually the best option is to dump quickly the remainder of the fuel into the snuffer can. However, with experience, the user might learn to re-ignite the secondary combustion. These are details of operation left for a separate discussion.

9. Results of emissions testing

Anderson’s “Champion” stove is the T-LUD gasifier [with natural draft air] that was measured and judged the cleanest burning of nine natural-draft biomass stoves at Stoves Camp 2005.





10. Other stove issues

Stove safety

11. Reports on experiences with TLUD gasification

1985-1996

1996-2000

2001-2005

2006-2007

2008-2010

12. Collection of photos, etc.



The “X” legs hold the horizontal bars that hold the stove’s upper body.



Stove structure is evident.



TLUD stoves made in India. Note the sliding connectors. Several are for water heating.

13. Fuel topics



Left: Coconut husks, dried, semi-charred, and charcoal.
Right: Coconut shells, some fully pyrolyzed.
Smaller pieces would be better.



Pieces of coconut fronds (leaves) that can be combusted in a TLUD gasifier.
The pieces should be smaller than these. Maximum 2 inch lengths.

14. Other