

Construction Plans for the “Champion-2008” TLUD Gasifier Cookstove (including operational instructions)

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All subsequent versions will be appropriately marked under the title.

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I. Introduction

The quest for clean combustion of wood and other solid biomass fuels in open cooking fires and arranged cookstoves is as ancient as human history. Still today, two billion humans destroy forests and inhale life-shortening smoke because they cook food with solid fuel. Beginning in 1985 – 1988, Thomas B. Reed in America and Paal Wendelbo in Norway and Africa worked independently and devised what is now known as top-lit updraft (TLUD) gasifier technology for cookstoves. Dozens, perhaps hundreds, of other “Stovers” have subsequently experimented and designed TLUDs of many types.

I met Tom Reed and his prototype gasifier with forced air (TLUD-FA) in early 2001. My goal was to make a successful natural draft version. In 2005 my TLUD-ND stove won an award for clean combustion and was named the “Champion” stove. Despite numerous efforts, it did not become a successful cookstove in markets or projects. In mid-2008, the general community of Stovers learned of the pioneer work of Paal Wendelbo and his “Peko Pe” TLUD-ND cookstoves. His story with photographs and construction details are at: <http://www.bioenergylists.org/wendelbopekope> Contact with him re-ignited my efforts to improve the Champion model. The results are in this document.

This new, smaller model is the “Champion-2008,” nicknamed “Champ.” Other names will probably be used when the stove enters into production with modifications in diverse communities.

I present specific designs created from experience, and based on core scientific principles relevant to TLUD-ND construction. Some readers want to follow a “How to” set of instructions. Others want an “Explanation of” what is essential, but still have the freedom to construct a unit using other materials and dimensions. This document tries to accommodate both approaches with comments and examples.

The reader of these construction plans should already be aware of the nature of TLUD gasification and how it works. This includes understanding terms such as primary air, secondary air, pyrolysis, char-gasification, top lighting, natural draft, low emissions, efficiencies, and more. If a review is needed, please refer to the TLUD information in “*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> And an overview of gasification (2004) at: <http://bioenergylists.org/stovesdoc/Anderson/GasifierLAMNET.pdf> And TLUD’s exceptionally clean combustion (2009): <http://www.bioenergylists.org/andersontludcopm>

There are no patents on the technology or designs, and I encourage others to make and modify any of these stoves. Indeed, I would like to communicate (by e-mail or otherwise) with individuals or entities who undertake to make or modify these gasifier stoves. There are dozens of meaningful research topics for students and academics. If considering commercial production, I will assist you if possible. Much discussion is on the “Stoves Listserv” that is accessible via <http://bioenergylists.org> and where there are countless published items and links about all types of cookstoves.

II. Construction Options

A. Four Versions of Champion-2008 TLUD-ND Gasifiers:

Four versions of essentially the same Champion TLUD are differentiated and defined by the raw materials and the tools (and skills) available to you. I describe here the use of sheet metal, tin cans,

screws and pop-rivets, but thicker metal (even clay and ceramics), and welding/brazing could be used if you are skilled with such materials and techniques. Likewise, we describe the use of hand-tools (tin snips, pliers, hammers, screwdrivers, *etc.*), but clearly mechanical shears, bending brakes, rollers, punches, and welding gear could be used. The focus of this paper is the fabrication of single units. Mass production of multiple units of the Champion TLUD by industrial manufacturing could readily be accomplished in a properly equipped factory or by an organized network of moderately skilled tinsmiths in developing societies.

Four versions (variations) of functionally equivalent Champ TLUD gasifiers can be defined by the raw materials and the tools/skills available to or chosen by the maker. All four versions have similar dimensions, but differ in appearance because of the materials and workmanship.

1. “Hobbyist” (This version has been produced at a residential garage workbench in the USA with materials from common hardware stores. It is most appropriate for tinkerers, Scouts, and serious stove developers/experimenters.)
2. “Refugee” (This version has been produced using a minimum of tools and recycled materials found in refugee camps. It is most appropriate for humanitarian relief efforts.)
3. “Artisan” (This version has been produced as a commercial product in a modest metalwork shop in Chennai, India. It is most appropriate for primarily manual production as a commercial product by small factories.)
4. “Industrial” (This version has not yet been produced. It is most appropriate for industrial mass-production utilizing much more machinery, capital investments, and large-scale marketing.)

B. Stove Structures

None of the Champ versions support on the gasifier the weight of the cookware or stove body. The support for the cooking vessel (pot, skillet, *etc.*) is provided by the “stove structure.” Stove structures will vary according to cookware and cooking styles. There are literally hundreds of possible structure arrangements compatible with the Champ as the source of heat. Although not recommended, a simple stove structure could consist of merely legs or walls or even two containers (see Fig. 2) to support a metal grate or two bars with a pot above the TLUD.

The wide variety of “stove structures” include single-burner, multi-burner, and plancha stoves. Even suspending a simple pot over a fire constitutes a complete cookstove (or cooking arrangement). Construction materials are generally bricks, mud, or metal. Use of wood, even when shielded from heat, is not a very good decision.

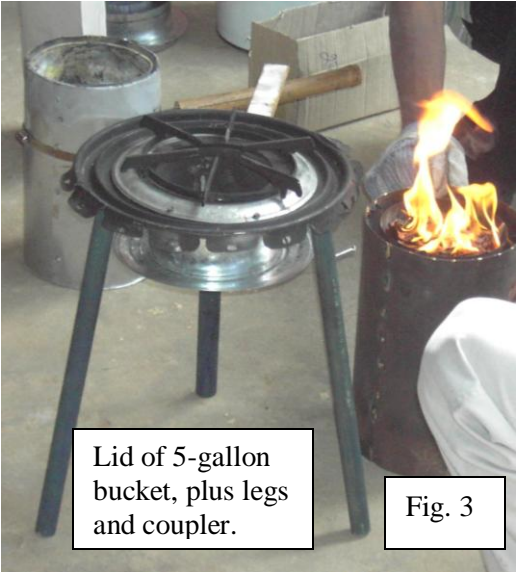
Similarly, there is a variety of sources of heat: open 3-stone fires, the “Rocket” chambers, charcoal burners, liquid-fuel burners, and the gasifiers (Peko-Pe, Champion-2008, Reed’s forced-air TLUD, *etc.*). Although with different combustion technologies, all of these are “heat generation units” or thermal energy units.” But none is technically a cookstove until it is integrated with a cooking application (stove structure) as mentioned above. Nevertheless, it is common to find references to a “TLUD cookstove” or “Rocket cookstove” or “alcohol cookstove,” *etc.* without reference to a specific stove structure because these heat sources can be built into so many different types.

The Champion-2008 TLUD-ND utilizes a “riser,” essentially an internal chimney below the pot, to improve the natural draft. The riser could be attached to the “concentrator lid” (see photos of the Refugee version) or be in the form of a “coupler” attached to the stove structure to better channel the heat to the cooking area. Therefore, possible attachment of the riser should be considered when evaluating options for stove structures.



Fig. 2: Shown is a Juntos B+ TLUD with forced air. (Source: Anderson and Reed LAMNET article in 2004.)

**Examples of stove structures.
Many more exist.**



Lid of 5-gallon bucket, plus legs and coupler.

Fig. 3



A 2-pot stove structure of mud with chimney.

Fig. 4



Fig. 5



Fig. 6

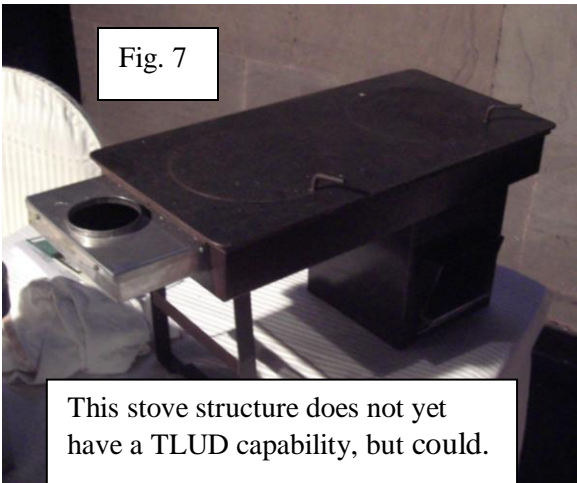


Fig. 7

This stove structure does not yet have a TLUD capability, but could.

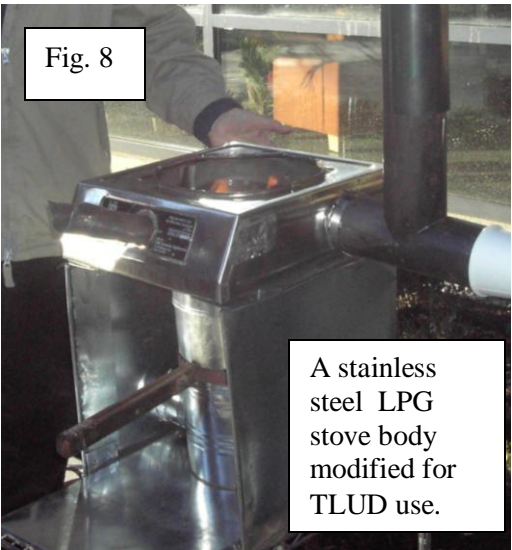


Fig. 8

A stainless steel LPG stove body modified for TLUD use.

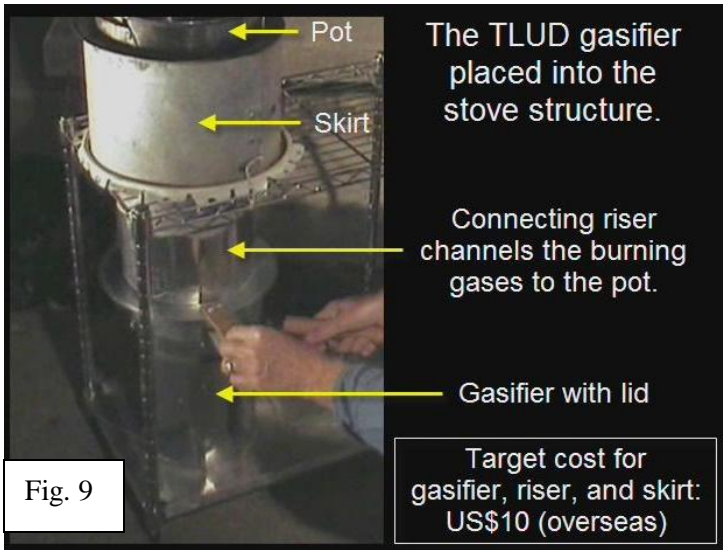


Fig. 9

The TLUD gasifier placed into the stove structure.

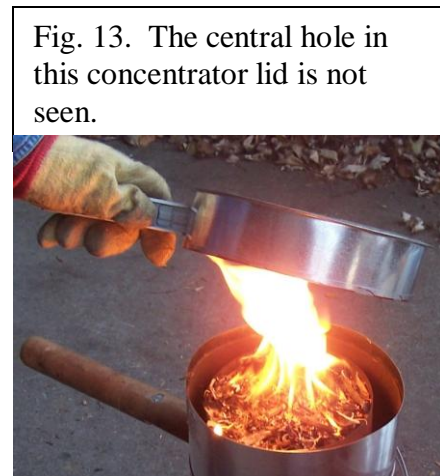
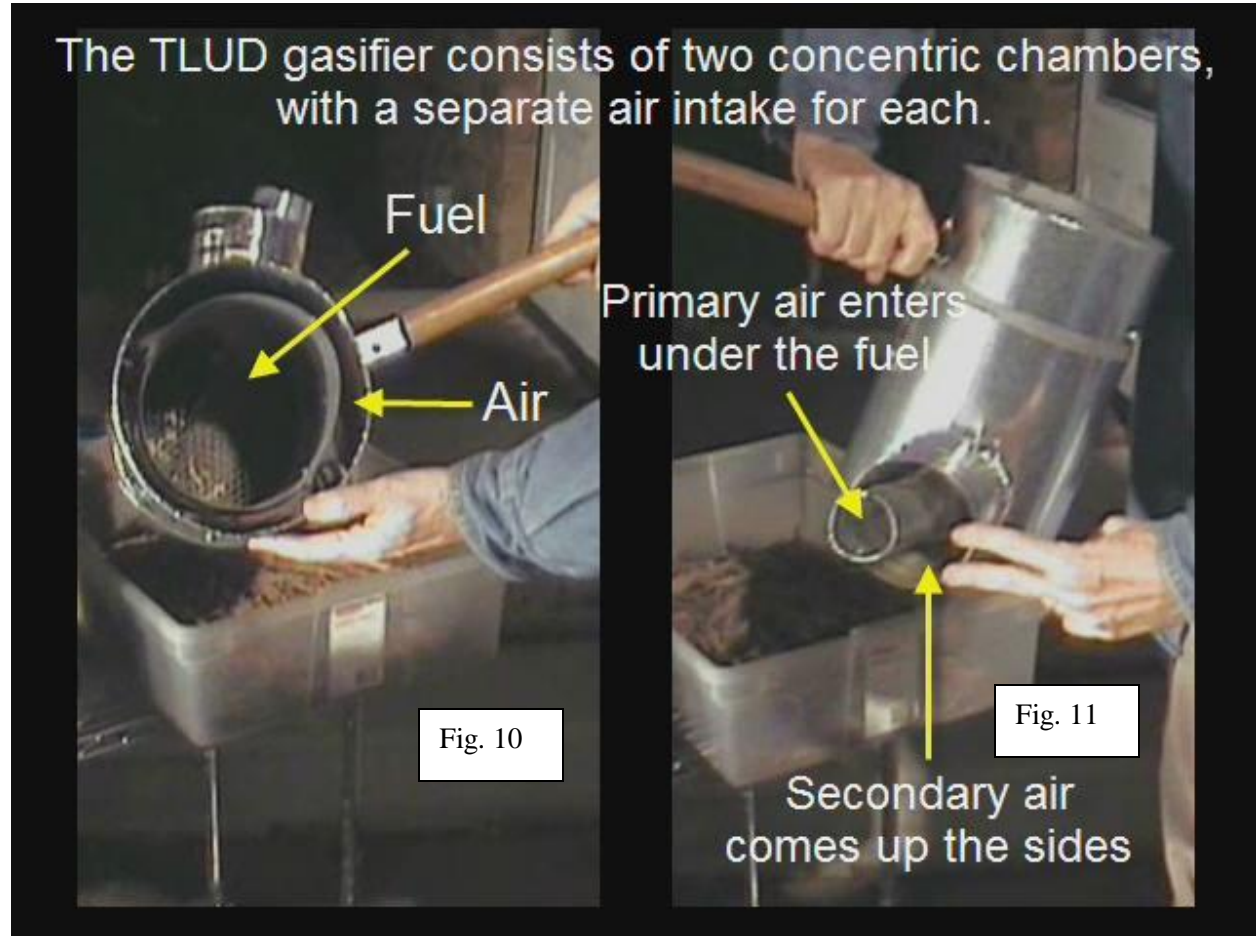
Connecting riser channels the burning gases to the pot.

Gasifier with lid

Target cost for gasifier, riser, and skirt: US\$10 (overseas)

C. Hobbyist Version of the Champion-2008 TLUD Gasifier

The materials are mainly standard sheet metal products from a good “home improvement” (hardware) store in America, plus a standard #10 tin can or coffee can. A YouTube video about this version is at: <http://www.youtube.com/user/seejayjames> The video starts with a 30-second summary prepared for the Google “Project 10-to-the-100” contest (with semi-finalist results to be announced in mid-March 2009), followed by an expanded viewing for less than three minutes.



D. Refugee Version of the Champion-2008 TLUD Gasifier

The materials are mainly two identical tin cans (approximately 5 liter capacity) used to distribute cooking oil to refugee camps. The inner one is unchanged except for insertion of the primary air duct and the metal fuel grate (which could have been the can's lid if punctured with many 5 to 8 mm holes). The outer cylinder is the side-only of the second can, cut vertically, expanded with a rectangular piece, and increased in its overall standing height at the bottom with a band that could also have been cut from another similar tin can. Note: The only section which will experience serious heat damage during operation of the unit is the lower 100 mm (4 inches) of the side walls of the inner can above the grate, so protection is recommended using an easily-replaced insert of a short cylinder of scrap metal.



Fig. 14



Fig. 15



Fig. 16

E. Artisan Version of the Champion-2008 TLUD Gasifier (manufactured in Chennai, India, January 2009)

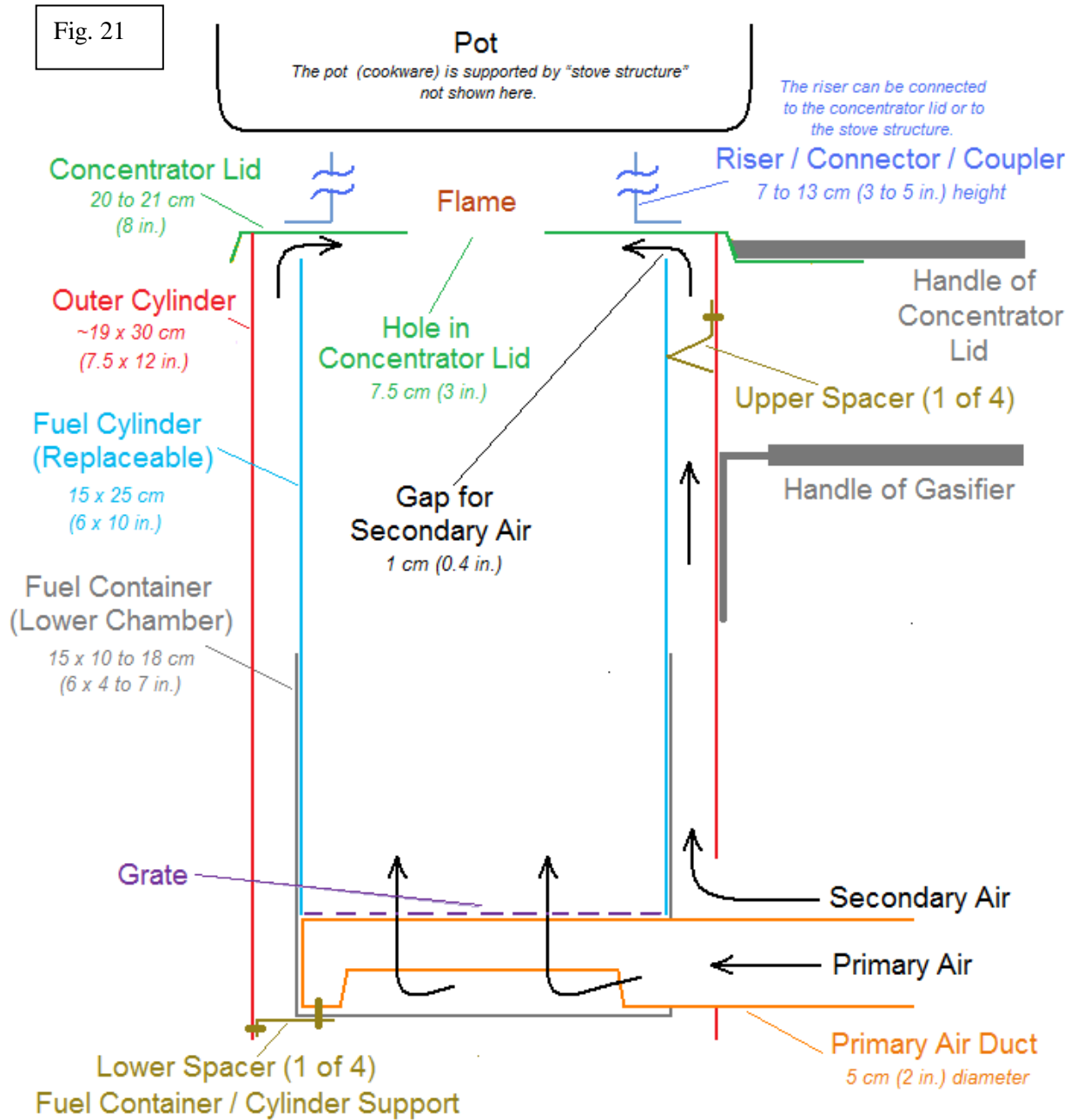
The materials range from mild steel sheet metal to stainless steel sheets. Some parts are standard Indian kitchenware that is cut and adjusted to serve as lids and handles and parts of the tripod stove structure.



III. Components

A. Vertical section with dimensions:

The vertical-section in Figure 21 below shows the various components common to all four versions.



The Champ TLUDs shown in the photographs are all approximately 8 inches (200 mm) in diameter and 8 to 12 inches (200 to 300 mm) in height. These same proportions apply when determining appropriate heights of Champ TLUDs with diameters ranging from 6 to 10 inches (150 to 250 mm). However, blindly changing the dimensions by 2x, 3x, 0.5x or 0.3x will not result in an optimal unit. We recommend that you do not try to make other sizes until you have experienced solid success with the 8-inch units introduced here. Then you have something with which to compare and improve upon. Sizes do influence the amount of fuel in the chamber and therefore the time and strength of the burning, but fuel types are also important. TLUD users quickly learn about such operational issues.

Dimensions are given in both inches and millimeters. Interestingly, inches are widely used internationally for cylinder diameters. Almost all of the dimensions are approximate and (unless stated otherwise) tolerate at least a 10% variation plus or minus, so 150 mm with plus or minus 3 mm is virtually the same as 6 inches plus or minus one-eighth inch. Also, we make no distinction between the Imperial (British) inch and the slightly larger Norwegian inch. Unfortunately there is no acceptance yet for a slightly smaller “metric inch” (or “minch”) that would be exactly 25 mm. The following is given for convenient reference if needed.

inch	mm	
1	= 25	[more precisely, 25.4 mm, being a difference of less than 2%]
2	50	
3	75	
4	100	
5	125	
6	150	
7	175	
8	200	

B. Initial Notes and Principles

To have some degree of control over the amount of heat produced per minute, the entry of primary air underneath the pile of fuel should flow solely through the primary air duct (that is, there should be no additional air-entry points or leaks in the lower part of the fuel cylinder). For this reason, tin cans with sealed bottoms are especially useful to those who are not skilled tinsmiths. In the Hobbyist version, the use of sheet metal ducting with manufactured caps is a temptation to avoid, as the seal between the caps and ducts is typically compromised by small gaps at the perimeter.



Fig. 22



Fig. 23

All natural draft cookstoves are dependent upon the upward flow of heated gases that causes a negative pressure (partial vacuum or suction) that draws new air into the combustion zones to sustain the chemical reactions commonly called burning. The vertical movement of air and combustible gases is important in terms of both volume and velocity. For example, the purpose of the concentrator lid is to increase the speed of the flaming gases through the hole that is smaller than the gasifier below or the riser above, thereby improving turbulence and mixing. This is the most distinctive shared feature and a key to success of both Wendelbo's Peko Pe and Anderson's Champion TLUD gasifiers.



Sufficient (even abundant) natural draft is crucial to successful operation of TLUD-ND cookstoves, especially when other factors (such as damp fuel, packed fuel, air leaks, and winds) restrict or disturb the air and combustible gas flows. Also, at elevations above 1000 meters (3000 feet), the height of the riser/coupler usually needs to be increased (depending on the stove structure being used). We do not present here the rationale for how the Champion stove obtains its natural draft. Just be aware that proper air ducting/drafting, internal combustible gas flows, and appropriate dry fuels are the most crucial factors impacting this cookstove's operation.

C. The Components of the Champion-2008 TLUD Gasifiers

Part 1: Fuel chamber, lower part

The most important part of the Champion TLUD is the lower half of the inner cylinder, known as the fuel cylinder or fuel chamber. To withstand the peak operating temperatures within this part, it must be made of steel. (Aluminum cannot withstand the heat. Ceramic options for this part are a special topic. Tin cans are acceptable because they are actually steel coated with tin, but they are quite thin and lack longevity.) This steel section should have a well-sealed bottom that is 6 to 6.5 inches (150 to 170 mm) in diameter, which is the diameter of #10 tins, coffee cans, gallon paint cans, cooking-oil tins sent to refugee camps, and certain tins used in some countries when purchasing powdered milk or motor oil. A metalwork artisan is equipped to manufacture precisely the desired size, using care to seal the bottom and maintaining at least 4 inches (100 mm) of height. With one exception, the taller heights of the various metal containers acceptable for use as the lower part of the fuel chamber are of no consequence. The one exception is when the height of the metal container is used as the total height of the fuel chamber, as in the case of the Refugee version in which the outer chamber has extra height added (previously discussed in Section II.D.).

Now we will focus on what must be done in the lowest four inches (100 mm) of the lower part of the fuel chamber.

Part 2: Primary air inlet

Into the bottom of the gasifier's fuel chamber (Part #1) there must be constructed a horizontal air duct made of steel sheet metal. See Photos and Figure. It should have an



Fig. 27

Primary Air Duct



Fig. 28



Fig. 29



Fig. 30

approximate 2-inch (50 mm) outside diameter. Preferably, this duct is cylindrical (tubular), but it can be a wide, rectangular duct with the same cross-sectional area (see photos of the Sampada stove by ARTI.) The cylindrical (tubular) shape is preferred (at least at the outside end) because it allows for easy blowing (by mouth-with-blow-pipe or by fan) when, during cooking, the user desires to increase the rate of heat generation.

Inside the fuel chamber, the incoming primary air must distribute freely under the grate that supports the fuel directly above. Therefore, the bottom half (underside) of the central portion of the air duct is cut away (See Figure 1). We do not want the air to flow along the walls, causing uneven combustion and unequal rates of pyrolysis. However, the India project stove uses only a short inlet duct, and the grate is supported by two crossed rods. For the Hobbyist and Refugee versions, the duct is recommended to extend across the fuel cylinder.

The total length of the metal for this duct is 10 to 12 inches (25 to 30 mm), being one inch at the inside end for tabs to be folded inward, plus 6 inches (150 mm) inside the fuel cylinder, plus approximately 5 inches (125 mm) continuing as the outside, radial projection. The outside portion could be shortened later.

A corresponding hole is made in the metal fuel chamber. If the chamber is a thin-walled tincan, the cutting is easy but the sealing is difficult. You should leave triangular tabs to be bent outward to surround the air inlet. When the air duct is inserted, the triangular tabs can be gripped by a hose clamp or secured with two short screws. A complete sealing of the hole surrounding the inserted primary air duct is difficult unless gaps are filled with furnace cement or braised. If braised, there is no need for the triangular tabs if the tinsmith has good metal cutting skills to match the hole and the inlet duct. If simple mud is used as the sealer, before each subsequent use the seal should be inspected and re-sealed when necessary. If there is minor air leakage around the inlet duct, the TLUD will still function properly, but it will be difficult to restrict the primary air intake during use.

Part 3: Fuel grate

The portion of the horizontal duct (Part 2) that is inside the lower fuel container (Part 1) acts as a support for the metal grate that holds up the fuel (see photo above). Expanded steel with a small mesh (one-eighth inch or 3 mm spaces) is very good in any of the versions. Grate size can vary according to the size of the pieces of fuel.

Alternatively, for the Refugee stove, the grate can be a **heavily** perforated disk of sheet metal or even the original lid from the tin can. Too few holes will restrict the flow of the primary air. Perforations can be made with a nail and a hammer (or rock). Place the grate so that the projecting (sharp) edges face downward. If the perforations are too large, smaller-sized fuel may fall through the grate. To reduce the fall-through, use slightly larger pieces of fuel, especially in the bottom of the fuel cylinder. Note, however, these larger pieces might not pyrolyze quickly enough during the final minutes of the pyrolysis stage, resulting (possibly) in smoke that is not combusted. [Remember: TLUDs are “smoke-burning” devices, so if the combustion of the gases stops at the top but the smoke generation continues in the fuel pile, there can be bothersome amounts of non-combusted smoke emitted from the unit.]

The grate can be held in place by pressure against the sides and/or by a sufficiently long screw coming up through the bottom of the fuel cylinder, continuing through the upper part of the primary air inlet duct, and finally through the grate. Otherwise the grate could inconveniently dislodge itself or fall completely out when the charcoal and ash are dumped out after a batch of fuel is used.

[Note: The upper section of the fuel chamber (Part 8) is the last component to be assembled and is subject to many variations relating to height and materials and preferences.]

Part 4: Outer cylinder

The outer cylinder serves several purposes:

- a. to channel and pre-heat the secondary air that rises and crosses over the top of the inner fuel cylinder in the gap under the concentrator lid. This also helps reduce the high heat to which the fuel cylinder is subjected
- b. to support the concentrator lid
- c. to support the inner fuel chamber approximately 10 to 15 mm above the bottom of the unit to minimize any problems of heat from the inner chamber radiating down and damaging the surface on which the unit is placed during its operation.
- d. to prevent direct exposure of the hot inner fuel chamber to minimize contact burns. Note that the risk of burns still exists because the outer cylinder can become quite warm.

The outer cylinder is about 1 to 1.5 inches (25 to 35 mm) larger in diameter than the inner fuel chamber, resulting in an annular ring (gap or air space) of 0.5 to 0.75 inch (12 to 18 mm) between the two main cylinders. The overall diameter of the outer cylinder is expected to be slightly less than 8 inches (200 mm) so that the concentrator lid can easily be placed over the cylinder and easily lifted off.

The outer cylinder has a hole (usually rectangular) through which the primary air inlet easily passes. The area of this hole around the primary air duct serves as the inlet for the secondary air, so the hole is rather large (approximately 3 x 4 inches or 80 x 100 mm). See photo below:

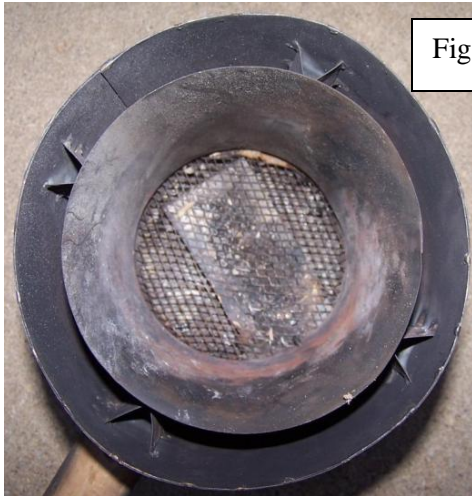


Fig. 31



Fig. 32

Especially in the Hobbyist version, the hole should be cut to maximize the available metal for supporting, connecting to, and elevating about a half inch (12 mm) the inner fuel chamber and primary air inlet.

There are several ways of elevating, supporting and centering the inner fuel chamber relative to the outer cylinder. See the photos for examples.

The height of the outer cylinder determines the height of the total gasifier unit. For user convenience and economy of labor by using the full dimensions of metal sheets, we use here the height of 12 inches (300 mm). Uniformity in height is important for interchangeability of gasifier units when queued for batch operation with two or more units. (Notes on operational instructions are in Section V.)

In general, it is easier to work with the sheet metal before it is closed into its cylindrical shape. This document does not attempt to explain all of the metal working techniques that can result in smoother edges or greater structural strength.

Part 5: Handle

Handles are important for the users convenience, but do not impact the gasification and combustion operation of the TLUDs. Issues about handles include position, length, shape, safety, and conduction of heat. The Peko Pe documentation describes one type (something like two “brackets” on the sides), and the Champion stoves pictured in this document have one radial-projecting handle.

The radial handle consists of a non-heat-conductive (usually wood) handhold approximately 10 inches long (250 mm) plus a metal attachment (usually “L” shaped) that joins it to the side of the outer cylinder (see last photograph in Part 4). The position of the handle is guided by the following considerations:

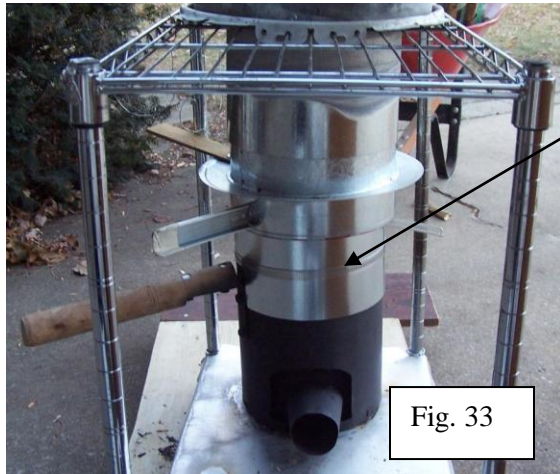
- a. The handle must extend outward from a point in the upper 25% to 40% of the height of the outside cylinder (because this improves its balance when holding, moving, or emptying the unit, and yet low enough not to interfere with the placement and removal of the concentrator lid.)

- b. When viewed from above the outer cylinder, the handle preferably projects outward directly in line with the primary air inlet duct, or up to 45 degrees to the left (clockwise from above) of that inlet, allowing the air to enter slightly from the right-hand side of the stove structure. (This seems to be best for right-handed people.)

c. More than one handle could be attached, but consideration must be given to the stove structure (legs, sides), the cultural preferences of the users, and any safety issues.

There are numerous ways to make the handle and to attach it.

The Hobbyist version with thin sheet metal shows the use of a hose clamp and a single screw, permitting easy repositioning of the handle if desired.



The Artisan version shows welded bolts through the sides of thicker steel. The Refugee version does not yet have an appropriately inexpensive way to attach the handle, but local ingenuity will certainly devise several options or could use a bracket-type handle.

Part 6: Spacers (several)

Spacers are used to secure the inner fuel cylinder in a central (concentric) position inside the outer cylinder. Because the upper portion of the inner fuel cylinder is a replaceable part (discussed below), the spacers are attached to the inside walls of the outer cylinder at points approximately 1 to 2 inches (25 to 50 mm) below the top rim. The dimensions and shapes of the spacers are not defined here because we have not required specific diameters for the inner and outer cylinders, so the space between them could be between 0.5 and 1.5 inches (12 and 40 mm).

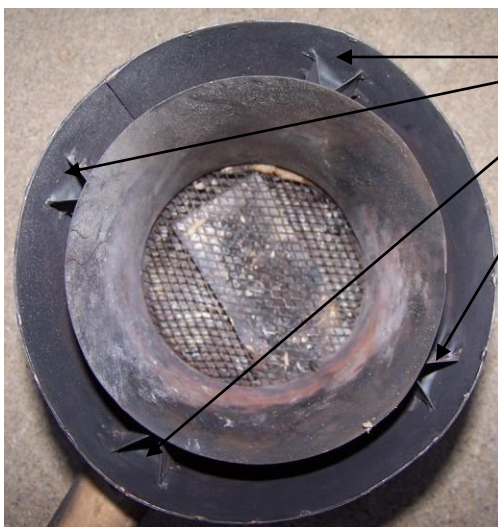


Fig. 34. Spacers between the cylinders.

Notes:

- a. Any screws or attachments for the handle can be utilized to hold (or actually become) a spacer.

- b. We recommend four spacers instead of the minimum of three, especially if the cylinders are made of the very thin sheet metal of ducts and tin cans.
- c. Spacers for the lower portion of the inner fuel chamber can be incorporated into the support required to elevate that chamber relative to the outer cylinder.
- d. Great accuracy in centering is not very important, but the inner fuel cylinder should NOT be significantly tilted relative to the outer cylinder to avoid custom cutting later of the replaceable upper part of the fuel cylinder. (Reason: The secondary air enters in the gap between the fuel cylinder and the concentrator lid that sits on the outer cylinder.)

Part 7: Concentrator lid, with handle

The concentrator lid could be simply a flat piece of steel with a 3-inch (75 mm) hole in the center. The metal must cover the entire top of the outer cylinder and be loose for easy placement and removal, probably about a half inch (3 mm) wider than the diameter of the outer cylinder. A circular lid tends to be the preferred shape, though not required (see below).

A downward “lip” or collar edge of 1 to 2 inches (25 to 50 mm) is desired to minimize the impact of wind blowing in under the lid and to provide rigidity. Do not make the collar too tall because the lid must easily be lifted off of and onto the gasifier in somewhat confined spaces. The Hobbyist version can use a standard 8-inch (200 mm) non-crimped duct cap if the outer cylinder diameter is 7.5 inches (190 mm) or less. (See the concentrator lid photographs in the Sections II and III above.) Fashioning a lid from a flat polygon shape (such as a hexagon or octagon) or even a slightly irregular shape can allow for simple bending downward of the sides from a single piece of metal.

The handle should be made of essentially non-heat-conductive material (usually wood). It should be radially joined onto the lid’s side collar (or onto a lateral extension of the flat lid) so that the handle is flush or slightly below the lid’s top surface. That is, the handle should not project onto the top of the lid where it could interfere with the riser / coupler. The weight of the handle must not cause the lid to be unbalanced and fall out of place.

There are important options about how the lid relates to the riser and coupler, but they are closely related to the stove structure and are discussed later.

Part 8: Fuel cylinder extension, upper part of the inner fuel chamber

The upper part of the inner fuel chamber is the last component to be assembled because it is subject to many variations relating to the other parts, the materials and secondary air supply.

When the concentrator lid is in place, resting on the outer cylinder, the top of the fuel cylinder should be approximately 10 mm (0.4 inches) below the lid. This gap provides for the entry of the highly important secondary air. If the gap is too large, the natural draft will draw excessive secondary air and incorrectly decrease the volume and rate of primary air that must come up through the fuel, resulting in cooling of the flame and less heat to the pot. If the gap is too small, the situation is reversed, resulting in excessive pyrolysis, insufficient secondary air, and in incomplete combustion and possible smokiness. Considering that particle sizes of raw fuel can be different and therefore facilitate or restrict the flow of the primary air, a specific gap can be better for a specific fuel. These variations are not yet well studied. Fortunately, the one centimeter gap seems to work very well in most cases.

The overall height of the fuel chamber is determined by the combination of its lower part (Part 1) plus its upper part (Part 8). Remember that there are variations in the heights of the possible containers used as the lower portion of the inner fuel chamber (Part 1). Therefore, we have two options:

One is to build the TLUD with a reasonably tall single-piece lower chamber (Part 1), eliminating the need for any upper extension (Part 8). This means adjusting the height of the outer cylinder (Part 4). For the refugees using the cooking-oil tins, the container height is sufficient, easy, available, and perhaps their only option.

The second option is to increase the total height of the fuel chamber by inserting an extension cylinder (Part 8). This involves inserting a simple metal cylinder fabricated to have a snug fit inside the lower (or base) container (Part 1). This cylinder will receive the greatest destructive thermal impact of

the pyrolysis and char-gasification, especially in the lower areas. Therefore, it is designed to be replaceable, and can be made of higher quality or thicker steel if desired. It is a simple cylinder that extends down inside of the fixed, lower Part 1 of the fuel cylinder, down to the level of the grate. [It can be made to slip past the grate if space is provided and if a notch is cut to match where the primary air inlet duct enters.] Because of this possible variation in the position of the extension cylinder, the height is subject to decisions and abilities of the maker.

The upper and lower parts of the fuel chamber are eventually held together (but not yet) by a small screw through the two overlapping walls. We need to have easy access to that screw so that we can remove/replace the extension cylinder when needed. The preferred place for this screw is in the area visible through the hole for the entry of the secondary air, close to the primary air inlet duct.

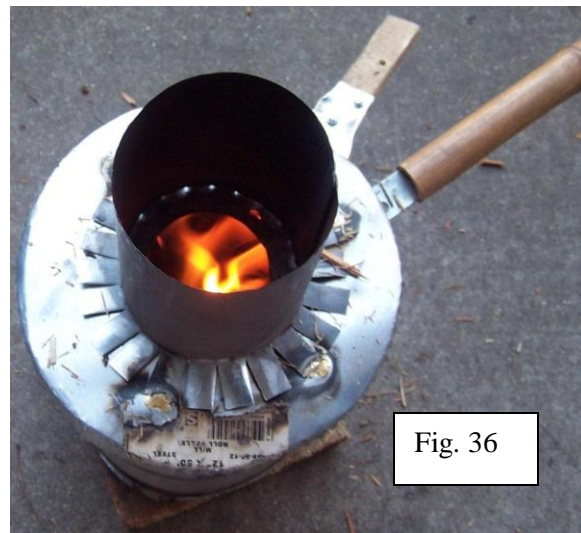
With this knowledge plus a decision on the overall height of the total TLUD gasifier (that is, the height of the outer cylinder, Part 4), the maker can determine the height of the upper fuel cylinder (Part 8) and proceed to assembly. The worst error in cutting the metal would only be making Part 8 too short. If it is too tall (meaning insufficient gap for the secondary air to enter under the concentrator lid), Part 8 could be removed, trimmed shorter, and reinserted.

Part 9: Riser/coupler

To accomplish sufficient natural draft, a “riser” is desirable. It is like a short “internal chimney” before the flames and heat reach the cooking pot. This riser is a cylinder approximately 4.5 to 5 inches (115 to 125 mm) in diameter, centered over the hole in the concentrator lid. An appropriate height is usually 4 to 5 inches (100 to 125 mm), but can be taller if needed, as in:

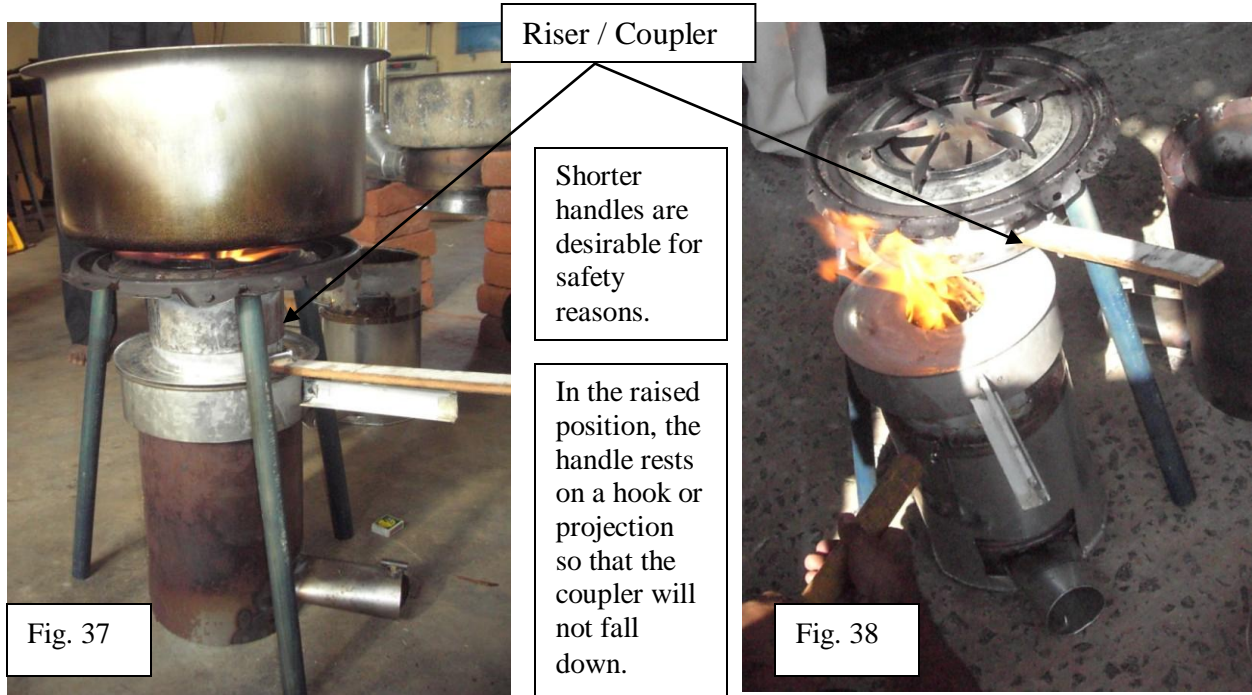
- a. Cooking at elevations above 3300 feet (1000 meters) because the air is thinner.
- b. Situations with difficult fuels that require additional draft.
- c. Special stove structures that justify the increased riser height.

Risers could be loosely sitting on top of the concentrator lids, but they would be awkward, unstable, and hot. There are various ways to attach a riser to the lid (rivets, screws, brazing, and even bent-metal tabs). Risers attached to the lids would be for the more simple stoves without a solid stove structure. See two photos below of an attached riser.



It is very easy to experiment with risers of different heights to see the great impact the riser causes. Put on a 2 foot (600 mm) section of ducting, and the combusting gases can cause an audible rumble (but the heat is almost 2 feet away from the cooking area.). In cookstoves with chimneys, the full extent of a hot chimney can produce similar fire intensities even though the riser is very short.

When the riser becomes an integral part of a stable stove structure, it essentially becomes a “coupler” between the concentrator lid and the stove body. It can have its own handle for moving it vertically. When in the down position, gravity keeps it sufficiently connected to the concentrator lid. One additional advantage of the coupler is that it can improve heat transfer to the pot because it does not allow unwanted air to enter near the pot, cooling the pot. See photographs below.



Part 10: Stove structure

Any of the versions of the Champion-2008 TLUD gasifiers can function as the heat source for a great variety of stove structures: large and small, fancy and simple, costly and inexpensive, and even efficient and inefficient. Except for situations of extreme poverty, the stove structure is the greatest cost and the most visible aspect of residential cooking. Essentially, the Champ TLUD gasifier unites described in this document need about 12 to 20 vertical inches (300 to 500 mm) of space directly under the primary cooking area.

In other words, many stove structures (whether new or used) can be adapted to having the PP-Plus natural draft TLUD gasifier as the heat-generation unit. This allows upgrading to TLUD clean thermal energy without dramatic changes in most existing (already paid for) or new (already in mass production) stove structures. Contact the authors if interested. Some photographs are in Section II.

IV. Assembly

1. Insert the assembled lower half of the fuel chamber into the outer cylinder, and fix it into place using the spacers and attachments.
2. Attach the handle.
3. Insert the upper part of the fuel chamber. Use a set-screw to prevent it from slipping from its position when the char and ashes are removed by tipping upside down.
4. Verify that the concentrator lid is correctly and completely assembled in relation to the stove structure with which the gasifier will be used.

V. Operational Instructions

(This section is a slightly revised version of “Basic Operations of Small Gasifier Stoves...” included in *Biomass Gasification: Clean Residential Stoves, Commercial Power Generation, and Global Impacts*, by Anderson and Reed (2004) available at:

<http://www.bioenergylists.org/stovesdoc/Anderson/GasifierLAMNET.pdf>)

A. Fuel: The fuel must be a “chunky” dry biomass, permitting airflow through the fuel bed. This airflow can also relate to the necessary height of the riser. 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 well 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 top of the fuel chamber (where the secondary air enters under the concentrator lid).

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* very 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. It can burn for a few seconds even without the concentrator lid, but the lid and the riser/coupler should be in place within 20 seconds to assure reasonable draft. When the flames stabilize in about a minute, and will probably increase slightly in the next few minutes as the natural drafting and pyrolysis will increase. 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 drafted air. The “pyrolysis front” is progressing downward through the fuel supply at a rate controlled by the amount of primary air entering via the primary air inlet. To increase or decrease the heat being produced, you can make adjustments to the amount of primary air during this time. You can blow gently into the inlet to increase the fire, or partially cover the inlet to reduce the fire. But try to avoid sudden shifts. Also, if an excessive gust of air (internal or external to the stove) OR deficient primary air extinguish the flame at the secondary air holes, there will be voluminous smoke (pyrolysis gases which are the fuel for the secondary combustion). A single match should be able to re-ignite the gases if conditions are correct, 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. But do not attempt this until you are quite familiar with the operations of TLUD gasifiers.

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 or clay pot 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 into position under the connector and pot.]

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.

VI. Further Notes

This section will grow in future versions / editions. All subsequent versions will be appropriately marked with the version number and date under the title.

VII. Conclusion

Because you have read this far, you are already in a “select” group of people who have interests in TLUD gasifier cookstoves. When you make one or more TLUDs and use them, you enter a rather “elite” group of people. And if you tell others or help others to understand and utilize TLUDs, you can be truly a “leader” in this technology. As of February 2009, there are extremely few truly involved individuals, but the numbers are starting to grow rapidly.

On behalf of all Stovers who work with these stoves, I hope that you become involved with TLUD gasifier cookstoves. We are interested in hearing of your experiences.



Fig. 39