Construction Plans for the
“PP-Plus” TLUD Gasifier Cookstove

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All subsequent versions will be appropriately marked under the title.

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I. Introduction

We, Paal and Paul, independently designed quite similar natural draft top-lit updraft (TLUD-ND) gasifier cookstoves, Wendelbo in 1988 and Anderson in 2005. Only in mid-2008 did we become aware of each other, and we have agreed to collaborate on future gasifier cookstove designs. The tentative name of the stove presented here is “PP-Plus,” signifying “Paal + Paul” or “Peko-Pe Plus,” meaning “something beyond” Wendelbo’s original Peko-Pe (“peh-co peh”) stove in Uganda. It might become simply the “Plus” stove or the “Juntos PP” stove (Juntos is Anderson’s trade-name and means “together” in Portuguese and Spanish). Other names will be used when the stove enters into production in diverse communities and with design modifications and improvements.

There are no patents on the technology or the designs, and the authors encourage others to make and modify the PP-Plus stove. Indeed, we would like to communicate (by e-mail or otherwise) with people who make this gasifier stove. Anyone interested in producing more than ten units or entering into commercial production is encouraged to contact us so that we can facilitate contacts with other producers and also assist in the subtle refinements that come only from many years of hands-on experience. This document cannot possibly include all that we know about making natural draft TLUD gasifiers that truly work.

This document assumes that you are aware of what TLUD gasification is and how it works. Terms like primary air, secondary air, pyrolysis, char-gasification, top lighting, natural draft, and more are important. If you need that background, please read the TLUD information in “Micro-Gasification: What it is and how it works” by Anderson, Reed, and Wever (2007 ??) (and give the URLs for both Hedon and Chip Energy copies)

II. Overview of Construction Options

There are specific practices as well as principles involved in TLUD-ND construction. Some readers want a “How To” set of instructions to follow. Others want to know what is essential, but have the freedom to construct a unit using other materials and dimensions. We will try to accommodate both approaches by our comments and examples.

Key variables include the raw materials and the tools available to you. We 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. We only discuss making single units; production of multiple units is an additional aspect of manufacturing. Let us be clear that a properly equipped factory could easily
mass-produce the PP-Plus TLUDs, as could a network of moderately skilled tinsmiths in developing societies.

We present three variations of the PP-Plus gasifier as defined by the raw materials and the skills/tools of the maker. [A fourth version for “Industrial” production utilizing much more machinery, capital investments, and large-scale marketing is not discussed here.]

1. the “Hobbyist” version (what has been produced at a residential workbench in the USA with materials from hardware stores. Appropriate for tinkerers, Scouts, and serious stove developers.)

2. the “Refugee” version (what has been produced using recycled materials found in refugee camps, with minimal tools. Appropriate for humanitarian relief efforts. )

3. the “Artisans” version (what has been produced as a commercial product in a modest metalwork shop in Chennai, India. Appropriate for small industrial production as a commercial product.)

All three of these versions of the “PP-Plus” design function the same and are similar in appearance.

All three do NOT support the weight of the cookpot on the gasifier. The support for the cooking vessel (pot, skillet, etc.) is the “stove structure.” Stove structures will vary with cooking styles. There are literally hundreds of possible structure arrangements that can be compatible with the PP-Plus as the source of heat. A simple stove structure is a set of legs or walls that support a metal grate above the TLUD. In some arrangements, the riser is also a coupler attached to the stove structure to better channel the heat to the cooking area.

Photographs of each version are on the next pages.
III. Components

The vertical-section shown in Figure 1 provides labels for the various components in all three variations.

The pot is independently supported by the “stove structure” that is not shown in this Figure 1.

The riser can be connected to the concentrator lid or to the stove structure.

Label changes on lower fuel chamber and on fuel cylinder extension.
Size and measurement considerations:

The PP-Plus TLUDs shown in the photographs are all approximately 8 inches (200 mm) in diameter and 8 to 12 inches tall (200 to 300 mm). The proportions are correct for diameters 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.

Dimensions are given in both millimeters and inches. Interestingly, inches are widely used internationally for cylinder diameters. Almost all of the dimensions are approximate and tolerate a 10% variation plus or minus, so 150 mm with plus or minus 2 or 3 mm is virtually the same as 6 inches plus or minus one-eighth inch. And we make no distinction between the Imperial (British) inch and the slightly larger Norwegian inch. The following is given for convenient reference if needed.

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Initial notes and principles

The entry of primary air underneath the pile of fuel should have NO LEAKS if you want to have some degree of control over the amount of heat produced per minute. 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 sheetmetal ducting with manufactured caps is a temptation to be avoided. The seal between the caps and ducts leaves many small gaps.

All natural draft cookstoves are dependent upon the ability of the heated gases to move upward, resulting in a negative pressure (partial vacuum or suction) to bring new air into the combustion zones so that the burning can continue. The vertical movement is important in both the volume and the speed of the gases. 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/mixing. Providing sufficient (even abundant) natural draft is crucial to successful operation of TLUD-ND cookstoves, especially if some other factors (such as damp fuel, packed fuel, air leaks, and winds) restrict or disturb the airflows. We do not present here the justification and rationale for how the PP-Plus stove obtains its natural draft. Just be aware that the airflows (and appropriate fuels) are the most crucial factors impacting this cookstove’s operations.
Part 1. Fuel chamber, lower part:

The most important part of the PP-Plus 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.) 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 some unique tins available in some countries when purchasing powdered milk or motor oil. A metalwork artisan is equipped to manufacture precisely the desired size, giving care to seal the bottom and have at least 4 inches of height (100 mm). The heights of these various metal containers are variable and discussed later. 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 and across 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 is to have an approximately 50 mm outside diameter (2 inches) on the outside. Preferably, this duct is cylindrical (tubular), but it can be a wide, rectangular duct with the same cross-sectional area. The cylindrical (tubular) shape is preferred because a circular cross-sectional area is maximized in density (the area is geometrically concentrated), which maximizes heat and could limit the ability to easily effect the effectiveness of blowing (by mouth-with-blow-pipe or by fan) when, during cooking, the user desires to increase the amount of heat being generated or raise the rate of heat generation.

Inside the fuel chamber, the bottom half (or underside) of the central portion of the air passage duct is cut away, allowing the incoming primary air to distribute freely under the grate that supports the fuel directly above. We do not want the air to easily reach the cut-away section to extend to either the near or far wall end of the inlet (because that will unfavorably cause extra air to flow along the far walls, causing uneven combustion and unequal rates of pyrolysis). So we bend inward some inch-long (25 mm) tabs cut into the far end of the inlet pipe. Make all the cuts before inserting. The total length of the metal is 12 inches (30 mm), being one inch for folded tabs at the inside end plus 6 inches (150 mm) inside the container plus approximately 5 inches (125 mm) projecting perpendicularly to the outside. This could be shortened later.

A corresponding hole is made in the metal fuel chamber, leaving triangular tabs to be bent outward to surround the air inlet. When the air inlet is inserted, triangular tabs can be gripped by a hose clamp or secured with two short screws. A complete seal 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 must 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 if needed during use.

Part 3. Fuel grate:

The inside portion of the horizontal duct (Part 2) acts as a support for the metal grate that supports the fuel. Expanded steel with a small mesh (one-eighth inch or 3 mm spaces) is very good. But 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 projecting (sharp) edges of the grate downward. If the perforations are too big, 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 pile of fuel. 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 side and/or by a sufficiently long screw coming up through the bottom of the can, through the upper part of the air inlet duct, and through the grate. Otherwise the grate could inconveniently dislodge itself or fall completely out when the charcoal/ash are dumped out after a batch of fuel is used.

[Note: The upper section of the inner fuel chamber 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.

b. to support the concentrator lid

c. to support the inner fuel chamber approximately 10 to 15 mm above the surface (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.

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 passes. The area of this hole serves as the inlet for the secondary air, so the hole is rather large (give size and show the pattern of the cuts).

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. Show and or describe.

The height of the outer cylinder determines the height of the total gasifier unit. The inner fuel chamber is adjusted according to the height of the outer cylinder. For user convenience and expected economy of sheet metal costs, 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.

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**

The handle consists of a non-heat-conductive (usually wood) hand-hold approximately 10 inches long (250 mm) plus a metal attachment (usually “L” shaped) that joins it to the side of the outer cylinder. 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) and the cultural preferences of the users.

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

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.

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. 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.

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 and placed 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 photo.) 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.

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 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 insufficient 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 incomplete combustion and possible smokiness. Considering that particulate 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 the lower part (Part 1) plus the 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 at the low height of the fuel container so that we do not need any upper extension (this 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 height of the fuel chamber using a 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 of the fuel cylinder 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.

**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 center of 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.

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 the chimney can produce similar fire intensities even though the riser is very short.

When the riser becomes an integral part of the stove structure (to improve heat transfer), it essentially becomes a “coupler” between the concentrator lid and the stove body. See photographs.

**Part 10: Stove structure**

A great variety of stove structures can be used with the PP-Plus TLUD gasifier: 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 PP-Plus TLUD gasifier components need about 12 to 20 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 heat without dramatic changes in most existing (already paid for) or new (already in mass production) stove structures. Contact the authors if interested.

The remainder of this document is still “in construction.” All subsequent versions will be appropriately marked with version number and date under the title.

**IV. Assembly**

1. Insert the assembled lower half of the inner fuel chamber into the outer cylinder, and fix it into place

**V. Operational Instructions**

**VI. Further Notes**

**VII. Conclusion**