PATENTS AND DESIGNS ACT, 1911

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Ref. Patent No. 170/ 2019/ 2333

Dated: 19 May 2021

NOTICE OF ACCEPTANCE

Under section 6 of the Patents and Designs Act, 1911 notice is hereby given that **Julien Peter Winter, Nationality: Canadian, and Md. Mahbubul Islam, Nationality: Bangladeshi,** filed a patent application no.170/2019 dated 03/07/2019 for the protection of an invention for **"TOP-LIT UPDRAFT GASIFIER COOKSTOVE/HEATER MADE WITH CONCRETE."** was accepted on 31/03/2021 and numbered as Bangladesh patent serial no.**1006389.**

The application, specification and Drawings (if any) are open to public inspection during office hours. The acceptance will be advertised in the Bangladesh Gazette and the printed specification and Drawings (if any) will be available in due course of time at a price of prescribed fee for each copy.

Within four months of the date of advertisement, any person may, under Section 9 of the Act, give notice of opposition to the grant of the patent. If there is no opposition, or in case of opposition, if the determination is in favour of the grant of a patent, and if the applicant desires a patent to be sealed, he/she shall file his/her request on Form 8 with prescribed fee in accordance with Rule 23 of the Patents & Designs Rules, 1933 within 24 months or 28 months (as the case may be) from the date of filing.

Ra
19.5.21

(Md. Rashedul Hasan Jibon)
Examiner (Patents)
on behalf of Registrar

To

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N.B. All communication should quote the number of this notice & should be addressed to the Registrar of the Department of Patents, Designs & Trademarks of the above noted address.

PATENTS AND DESIGNS ACT, 1911

Form 3

Provisional Specification. Section 4.

(To be supplied in duplicate with Form 1, 1A, 1B, 1C, 1AC, 1BC or 1CC.)

(1) Top-Lit Updraft Gasifier Cookstove/Heater Made with Concrete

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(3) The following specification describes the nature of this invention:-

TOP-LIT UPDRAFT GASIFIER COOKSTOVE/HEATER MADE WITH CONCRETE

BACKGROUND OF THE INNOVATION

This patent describes a TLUD (top-lit updraft) gasifier stove that was designed for general purpose cooking and making biochar in rural households. Our objective was to design a culturally appropriate stove that could be made by regional artisans. To this end, we used ideas from existing TLUD technology, and combined those ideas with local knowledge on using heat-resistant concrete for making cookstoves.

A TLUD gasifier burns wood or compressed biomass in an oxygen-limited fire creating pyrolytic volatiles (‘white smoke’) and char. Biomass fuel is batch-loaded into the reactor (usually a vertical cylinder) to create a fuel bed. At the bottom of the reactor is a grate through which primary air enters and moves upwards through the fuel bed. The fuel bed is ignited on top resulting in an oxygen-starved fire that is controlled by regulating a low velocity of primary air that rises through the fuel bed from the grate. This fire creates an ignition front that moves slowly down from the top of the fuel bed through the unburned fuel creating temperatures ranging from 550-1200 °C (depending on the velocity of primary air, and the type and thickness of fuel) as it proceeds. High temperatures at the ignition front cause pyrolysis of the fuel particles into (1) a flammable ‘white smoke’ of volatiles (containing gases such as H_2, CO, CO_2 and light hydrocarbons, as well as suspended droplets of tar and fine solids) and (2) a residue of char and ash.

The residual char is about 10-25% (dry w/w) of the original fuel. Depending on the flow rate of primary air, ≥25% of the pyrolytic volatiles burn at the ignition front, which helps to generate the heat that drives the pyrolysis of raw fuel. Heat is also generated by glowing char. Above the ignition front, the char stops burning, because all the oxygen in the primary air has been consumed. Unburned volatiles rise though residual char to the top of the reactor. At the top of the reactor, volatiles combine with secondary air in a gas burner and burn as a ‘gas’ flame. Heat from the gas flame is used for cooking or heating.

The ignition front moving downward through the fuel is also called a 'migrating flaming pyrolytic front.' When the fuel particles are small, such as 6 mm biomass pellets, the pyrolytic front is narrow (e.g., < 1 cm), but when chunks of wood are used, the pyrolytic front is less well defined.

Once the pyrolytic front reaches the grate at the bottom of the reactor, the production of volatiles stops as primary pyrolysis is completed. The gas flame at the top of the TLUD will go out. At this point the operator of the TLUD can let residual char burn as charcoal, or they can remove the char from the TLUD, quench it, and keep it for other purposes such as charcoal, biochar, or for manufacturing. For an excellent introduction to TLUD stoves and examples of several models, see Roth (2013)

Char produced in TLUD stoves can be used as biochar; a fertilizer added to soil to increase soil organic matter, and soil productivity. In 2013, a colloquium on biochar was hosted in Dhaka by Mr. Joyanta Adhikari (Executive Director, CCDB) at the Christian Commission for Development in Bangladesh (CCDB). At this colloquium it was proposed that TLUD cookstoves could be a sustainable way of making biochar for rural families, because the stoves would simultaneously make char, increase cooking efficiency, and greatly reduce smoke inhalation by women (Johnson et al., 2019), whilst using the same wood and compressed fuel that was already being burned in traditional cookstoves. However, there was a need to design a TLUD stove for the Bangladeshi market. Foreign TLUD stoves were not optimum for Bangladesh, because they were made entirely of costly metal, were too light weight, and were culturally unfamiliar. Thus, we decided to design a TLUD cookstove for Bangladesh by combining existing TLUD technology with local methods already being used to make improved cookstoves.

A biomass cookstove called the 'Bondhu Chula' has played a key role in advancing the use of heat-resistant concrete for building stoves in Bangladesh. The Bondhu Chula was developed in 2009 by Dr. M. Kalequzzammen and E. Otto Gomm (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Dhaka) (Gomm, pers. com., 2020) by refining clay stoves designed in the 1980s by Dr. A. M. Hasan Rashid Khan and colleagues at the Institute of Fuel Research and Development of the Bangladesh Council of Scientific and Industrial Research (Golam Hossain, 2003). By using concrete, components of the Bondhu Chula could be reproduced reliably by sanitary engineering shops around the country. Kalequzzammen and Gomm recommended a concrete mixture composed of sand, clay brick fragments and Portland cement (3:2:1 by volume), reinforced with wire netting, and water cured for 7 days (Gomm, pers. com., 2020). Reinforcing maintains structural integrity if the concrete cracked. (Note: even refractory concrete can crack with uneven heating and cooling.) Once assembled, the components were coated with clay to protect the concrete from high heat. Thanks to the Bondhu Chula program, skilled artisans are now widely available to cast concrete for any stove.

The TLUD stove described in this patent was designed following the 2013 colloquium at CCDB. It was intended as a general-purpose stove that would be used to evaluate the acceptance of TLUDs and biochar in rural Bangladeshi homes. Our stove combines existing TLUD technology with local concrete technology to produce a robust, semi-permanent, cooking platform.

The TLUD stove described herein is patented as *open-source technology* to present our innovations to the public for duplication, improvements and customizing to meet particular needs.

CAUTION: Despite TLUD stoves having low emissions compared to traditional '3-stone' stoves (Johnson et al., 2019), TLUD stoves should be operated in well-ventilated conditions. The emission of fine particles is not completely eliminated. Chimneys and fume hoods should be considered.

PRIOR ART

Scientific History of TLUD Gasifiers

TLUD gasifiers are also called 'pot stoves' and 'inverted down-draft gasifiers.' In the 1930s TLUDs were used in combustion science laboratories to study the properties of biomass and coal fuels (Nicholls, 1934; Rogers et al., 1972; Starley et al., 1985). Since the 1940s, laboratory TLUDs have been used to model combustion in industrial chain grate (Marskell and Miller, 1946) and moving grate gasifiers (Stubington and Fenton, 1984). The primary and secondary air in these laboratory TLUDs was forced draft. In the years following, there have been ca. 100 academic papers in English that used forced-draft, laboratory TLUDs to model industrial gasifiers. Thus, the basic science of TLUDs is public knowledge: (i) a vertical, cylindrical, reaction chamber containing a fuel bed that is ignited on top, producing a downward-migrating pyrolytic front that is sustained with an updraft of primary air supplied though a grate at the bottom of the cylinder; and (ii) volatiles released by pyrolysis that are burned in a gas flame that is sustained by secondary air supplied at the top of the reaction chamber.

The TLUD described in our patent uses this public knowledge for gasifying batches of fuel in a cylindrical reactor and combusting the pyrolytic volatiles above in a 'gas' flame.

History of the Portable, Metal, TLUD Cookstoves

In the 1980s, TLUDs left the combustion science laboratory when portable, forced draft cookstoves were developed in the USA by Dr. Tom Reed and colleagues (La Fontaine and Reed, 1993; Reed et al., 2000). Other major research programs on forced draft TLUDs were led by Alexis Belonio (2005) in the Philippines and by Dr. H.S. Mukunda in India (Mukunda et al., 2007, 2010; Varunkumar et al., 2013).

Natural draft TLUD cookstoves were developed in the USA in the late 1990s and early 2000s by Dr. Tom Reed and Dr. Paul Anderson. In Norway, quite independently, Paal Wendelbo also developed a natural draft TLUD stove. This history of natural draft TLUDs has been documented by Anderson and Schoner (2016). The ideas were offered as open-source technology.

The forced and natural draft cookstoves were portable and made from stainless steel. They had a cylindrical, reactor chamber for gasification of a batch of fuel. Gasification was regulated by the flow rate of primary air through the bottom of the reactor chamber. The hot metal surface of the reactor cylinder was protected by enclosing it within an outer metal cylinder. Secondary air was passed through the annular gap between these two cylinders and was thus preheated by the hot outside wall of the reactor chamber. The preheated secondary air was combined with pyrolytic volatiles at the top of the reactor chamber to support a 'gas' flame. Commonly the secondary air was introduced to the volatiles by one of two means: (1) Forced-draft TLUDs and some natural draft TLUDs produced jets of secondary air through a ring of holes in the sidewall of the reactor cylinder, whereas (2) the natural draft TLUDs invented by Wendelbo and Anderson introduced a sheet of secondary air over the top of the reactor cylinder wall, then forced the burning pyrolytic volatiles through a circular aperture in a horizonal plate. This type of gas burner was called a 'concentrator ring'.

The TLUD described in our patent uses preheated secondary air after La Fontaine and Reed (1993), and a type of concentrator-ring gas burner after Wendelbo and Anderson (Anderson and Schoner, 2016). The inventors generously made their innovations public.

As the use of TLUD technology for cookstoves became known, patents were obtained for specific stove designs (below). Our innovation is of a similar kind where we have applied general knowledge to design a specific application.

Patents for metal, natural draft TLUD stoves were taken out by:

i) Hall, JB. 1998. Portable wood burning camp stove. US Patent 5,842,463 A: describes a natural draft TLUD that uses the same principles made public by La Fontaine and Reed (1993). It has a cylindrical reaction chamber with a ring of holes in the sidewall of the top of the cylinder for preheated secondary air. Char can be collected or burned to ash.

ii) Reed TB. 2003. Process for making a gas from solid fuels and burning the gas in a closed coupled combustor to produce clean heat. US Patent 2003/0200995 AI: patents the general principles behind natural draft TLUD cookstoves that he, along with Hottenroth, La Fontaine, and Larson, had been developing since 1985 (La Fontaine and Reed, 1993; Anderson, 2016).

iii) Doge, S. 2007. Woodgas stove with natural convection. German Patent DE 202007010436 U1: describes a natural draft TLUD no different in principle from La Fontaine and Reed (1993), and the two patents above (Hall, 1998; Reed, 2003).

Patents for metal, forced draft TLUD stoves were taken out by:

iv) Reed, TB. 2003. Process for making a gas from solid fuels and burning the gas in a closed coupled combustor to produce clean heat. US Patent 2003/0200995 AI: patents the general principles behind forced draft TLUD cookstoves that he, along with Hottenroth, La Fontaine, and Larson, had been developing since 1985 (Anderson, 2016).

v) 傅友红, 樊峰鸣. 2006. Hollow ring container multi-order air feed high class biomass cooking furnace. Chinese patent CN201014515Y: burns pellet fuel or peanut shells in a forced draft TLUD with a reactor shaped like a thermos bottle and having holes for secondary air at the narrowing top of the bottle. It has a chimney. Fuel is completely burned to ash.

vi) Mukunda, HS; Paul, PJ; Rajan, NK; Dasappa, S; Sridhar, GR; Shidhar, HV. 2007. Biomass Stove. World Intellectual Property Organization patent WO2007036720A1: burns pellet fuel in a forced draft TLUD with separate regulators for primary and secondary air. This was commercialized in India as the 'Oorja Stove'. Research was continued by Varunkumar et al. (2013)

vii) 别如山, 鄂佐星, 修太春, 王庆功, 朱伟, 张缨. 2008. Biomass shaping fuel-combustion countryside cooking/bathing/heating integrated apparatus. Chinese patent: CN101430102A: burns briquette-sized fuel in a very elaborate force-draft TLUD with water-heating system incorporated into its chimney. The reactor is cylindrical with broad, conical constriction at the top containing holes for jets of secondary air. It has a side chute for continuous refueling. Fuel is completely burned to ash.

viii) Mulcahy, N. 2011. Device and method for gasification and/or pyrolysis, or vaporization of combustible materials. US Patent US2011209698A1: describes a novel vortex burner for a forced draft ‘micro-pyrolyzer’ cookstove that has design features like a TLUD, although it is claimed not to function that way, but as a “top-lit opposing draft” (TLOD) pyrolyzer. The TLOD claim has not been proven.

ix) 李洪峻, 高怀斌, 黄光宏, 李俊. 胡云俊. 2013. Strengthened-discharging-type cooking stove. Chinese patent CN203549916U: burns pellets or peanut shells in a forced-draft TLUD with a thermoelectric power generator. It has a side chute for continuous refueling. Fuel is completely burned to ash. It has a chimney.

x) 毕晟, 江伟权, 陈斌, 贺暕, 朱健健, 胡茗崎, 任世成. 2014. Biomass cooking stove based on TLUD gasification principle and thermoelectric power generation technology. Chinese patent: CN104006413A: burns pellets or peanut shells in a forced-draft TLUD with a vortex gas burner, like that of Mulcahy (2011, US2011209698A1). In has a thermoelectric power generator. Flue gases are directed past a cooking pot to a hot water tank before exiting through a chimney. It does not have a side chute for refueling and is batch fed. It is designed to produce char to be saved.

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DESCRIPTION OF THE CONCRETE TLUD STOVE/HEATER

The TLUD stove/heater is composed of five modules stacked on top of each other (Figure 1). From bottom to top: (A) the base (Figure 2, Fig. 3, Fig. 4, Fig. 5), (B) the reactor (Figure 6), (C) the stove body (Figure 7), (D) the gas burner and riser (Figure 9 and Figure 10), and (E) the pot holder. The cookstove described in this patent is sized for a rural home with 4-5 people, using wood and biomass briquettes as fuel. For other situations, the dimensions (diameter and height) of TLUD heater/cooker can be varied according to the required heat output, and duration of burning.

Base Module

The Base Module (Figure 2) is the supporting foundation for the stove. It is made of heat-resistant concrete (Figure 3) with a protective coating of clay. It also functions to receive char dumped from the reactor (*k*) (Figure 6), and to regulate the entry of primary air into the stove. On top, it has a metal hinged grate (*h*) (Figure 2, Figure 4) that holds the fuel in the reactor until it is fully charred; at which point, the stove operator opens the grate to dump the char into the basal chamber. Then they remove the char through a side door (*d*) (Figure 2) and quench it. Primary air is regulated by a sliding door (*e*) (Figure 2) covering a triangular orifice (*c*) (Figure 2). The Base Module sits on a concrete plate or plinth (*a*) (Figure 2, Figure 4A) and is covered by a concrete top plate (*j*) (Figure 2, Figure 4B). A clay paste applied to concrete surfaces improves the seal between concrete components of the Base Module.

Reactor Module

The Reactor (*k*) is a vertical, metal cylinder (Figure 6). Its function is to contain the TLUD gasification reactions; in particular, the primary pyrolysis. There are several small holes in the sidewall of the reactor (Figure 6A). These holes ensure that a minimum amount of air enters the reactor so that the gasification reaction does not stop, and pilots the gas flame so that it does not go out (which would create a lot of smoke). The diameter of the reactor determines the maximum power output of the stove, and the height of the reactor determines the duration of gasification. If the dimensions of the reactor are changed, then other stove components will need to be proportionally resized. In our stove, the metal cylinder can be inverted to prolong its useful life. Metal cylinders, of the kind illustrated, are common to TLUD stoves and are not unique to our design.

Stove Body Module

Enclosing the reactor (*k*) (Figure 6) is the Stove Body made by stacking concrete rings (*l*, *m*) on top of each other (Figure 7). The body is a major structural component of the stove/heater, functioning to bear the load of the Burner Module, and provide a stable platform for a cooking pot. The body encloses the reactor and protects TLUD operators from the dangerously hot surface of the reactor. At the same time, the hot surface of the reactor can be used to pre-heat secondary air that enters through holes (lower ring *l*, Figure 7, Figure 8) in the bottom of the Stove Body, and then passes up through the annular gap between the outer surface of the Reactor and the inner surface of the Stove Body. The pre-heated secondary air passes over the top of the reactor and into the pyrolytic gas burner; namely, the 'concentrator ring'.

By making the Stove Body out of a stack of concrete rings, rather than a single cylinder, it is easier to manufacture, and it is more resistant to cracking due to the uneven distribution of heat radiating from the Reactor. It is also easier to repair. The heat-resistant, concrete rings are coated and sealed with clay paste to protect them from high temperatures. Reinforcing wire is embedded in the concrete to maintain structural integrity if the concrete cracks.

Gas-Burner and Riser Module

Gasification of biomass in the Reactor creates pyrolytic volatiles (PV) and char. The PV are flammable, and they burn in the presence of pre-heated secondary air (above). Ignition of the PV starts at the top of the reactor module and flaming combustion continues in the Gas Burner (Figure 9). The Gas Burner sits on top of the stove body (Figure 7). It has a nozzle in the center of the burner that functions to force PV and secondary air together.

Burner-Riser Module is made from wire-reinforced concrete coated with clay (Figure 9 & Figure 10). At the bottom of the Burner-Riser Module is a burner support ring (*n*) (Figure 9) that has a central hole (6 inches diameter) sufficiently large enough to permit the stove operator to load fuel into the reactor. The support ring sits on top of the Stove Body (Figure 7).

On top of the support ring (*n*) is placed the Nozzle-Riser (*o*) (Figure 9) which can be lifted free so that fuel can be loaded through the center of the support ring.

The 3-dimensionsal nozzle functions in the same way as the 2-dimensional hole in a metal plate that was invented by Paal Wendelbo and Dr. Paul Anderson (Anderson and Schoner, 2016); it is called a 'concentrator ring,' and is widely used, open-source technology. The aperture of the nozzle orifice should be sufficiently large so as to not impede the flow of burning gas. Thus, a laminar flame should occupy not more than about 3/4 of the orifice diameter. If the orifice is too small, the flame will exhibit a sustained pulsing in height, at a low frequency between 1-3 Hz. This is caused by pressure build-up and release below the burner. The pulsing is usually audible.

The PV flame exits the aperture of the Nozzle into a bowel-shaped space above created by a Riser (*o*) (Figure 9 & Figure 10). The Riser forms a circular wall above the Nozzle that contributes to a chimney effect that draws primary and secondary air into stove. The Riser forms a bowel-shaped space under a cooking pot that helps to spread out the contact area between the hot flue gases and the bottom of the pot. Bowel-shaped risers of this kind are common around the World with single-mouth biomass cookstoves.

The concrete components of the Burner-Riser Module are painted with several coats of clay slip to protect the concrete from heat. Re-painting the components with clay is part of regular stove maintenance.

Our nozzle burner is unique, and nobody has ever made a concentrator-style gas burner out of concrete and clay.

Pot Support Ring

On top of the PG burner is a generic metal pot support ring (*p*) that cradles the cooking pot above the PG flame (Figure 9).

Modifications

The stove illustrated in this patent is designed for general purpose household cooking. Its dimensions can be modified to suit other purposes.

Increasing the diameter of the stove Reactor (*k*) (Figure 6) increases the power output. Other stove components will have to be resized proportionately. Larger diameter stoves are needed for institutional or industrial settings (e.g., parboiling rice).

Increasing the height of a batch of fuel will increase the duration of heating, so the height of the Reactor (*k*) (Figure 6) and Stove Body (*l*, *m*) (Figure 7) can be customized. For example, to burn for the same amount of time, a reactor specifically designed for pellet fuels would be half the height of a reactor used to used to burn chunks of wood or briquettes, because the bulk density of pellet fuel is higher.

The Base Module (Figure 2) could be more airtight. The base module in this patent is sufficiently airtight for use with a concentrator ring or nozzle burner. However, other types of gas burner (e.g., a counter-current burner) create a greater buoyance force, and stronger draft of primary air. In such cases the primary air must be tightly regulated to turn down the stove.

The riser (*o*) and potholder (*p*) (Figure 9) illustrated in this patent were designed for general purpose cooking with various pots. Reshaping the riser-potholder for a specific pot or griddle can achieve better contact between the surface of the pot and hot flue gases, and thus increase the efficiency of heat transfer to the food.

CLAIMS

We claim:

1. a TLUD (top-lit updraft) biomass gasifier stove made from metal and heat-resistant concrete coated with clay, and that is composed integrated modules being (A) the base (Figure 2, Fig. 3, Fig. 4, Fig. 5), (B) the reactor (Figure 6), (C) the stove body (Figure 7), (D) the gas burner and riser (Figure 9 and Figure 10) and (E) a pot support (Figure 10).

2. a TLUD biomass gasifier according to claim 1 that has a concrete base module (Figure 2, Fig. 3, Fig. 4, Fig. 5) with a plinth (*a*); a concrete base box (*f*) having a char clean-out hole (*b*), a char clean-out door (*d*), a wedge-shaped, primary air inlet hole (*c*), and a primary air regulator door (*e*); on top of the concrete base box is a metal grate with two hinged flaps (*h*) and grate handles (*i*) that hold the grate closed when supported with a grate handle support block (g); and resting on top of the concrete base box and over the grate is a concrete base top plate (*j*).
3. a TLUD biomass gasifier according to claim 1 that has a cylindrical metal reactor (*k*) (Figure 6) that holds the fuel for gasification, and that has small holes in the side of the cylinder wall to ensure a minimum amount of air reaches the fuel for stable gasification and to pilot a stable gas flame.
4. a TLUD biomass gasifier according to claim 1 having a cylindrical reactor according to claim 3 that is surrounded by a concrete stove body (Figure 7) consisting of three concrete rings (*l, m*) stacked upon each other producing an annular gap between the stove body and reactor, at the bottom of which is 1-inch of sand that holds the reactor cylinder in place, and above which external air — entering through holes in the lower stove body (*l*) — can rise and be warmed by the hot reactor walls.
5. a TLUD biomass gasifier according to claim 1 having a cylindrical stove body according to claim 4, upon which rests a unique gas burner and riser (Figure 9 and Figure 10) made from reinforced concrete coated with clay, and having the burner support ring (*n*) at the bottom, followed by a nozzle orifice and riser (*o*) on top of that, and a metal cooking pot support ring (*p*) at the very top.
6. a TLUD biomass gasifier according to claims 1-5 that can be manufactured in sizes different from the scale illustrated in this patent according to the density of the fuel being gasified, and the amount of heat that needs to be generated.

All the above claims (1-6) that are presented by this patent are *open-access and for free public use*.

Md. Mahbubul Islam

Julien Peter Winter

Dated the Wednesday, October 02, 2020.

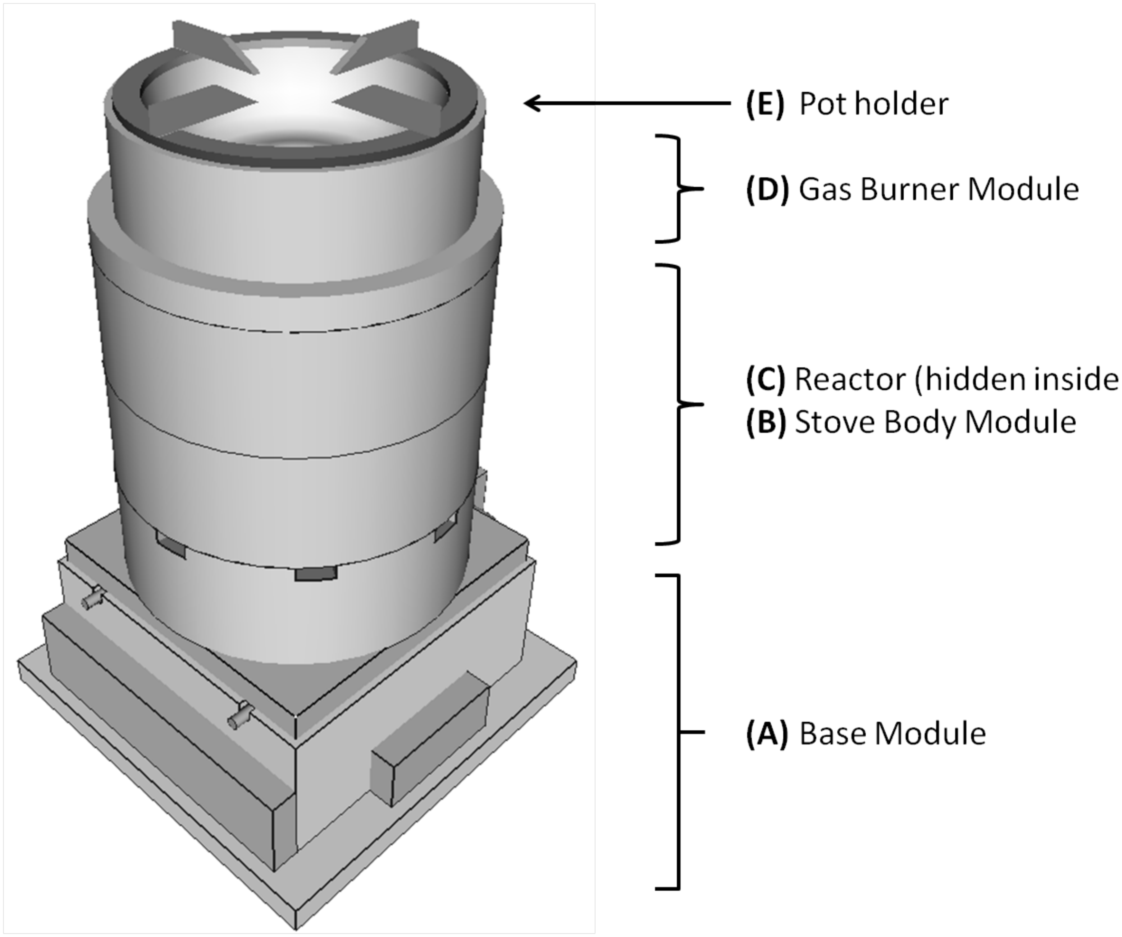

Figure 1. A modular concrete TLUD cooker/heater. The modules are from bottom to top: (A) a base for receiving ash & char and controlling primary air, (B) a metal gasification reactor that is contained within (C) a concrete or clay stove body with (D) a gas burner and riser on top, and finally, (E) a potholder. The illustration is an example of a cookstove designed to burn small pieces of wood and biomass briquettes for a family of about 4-5 people.

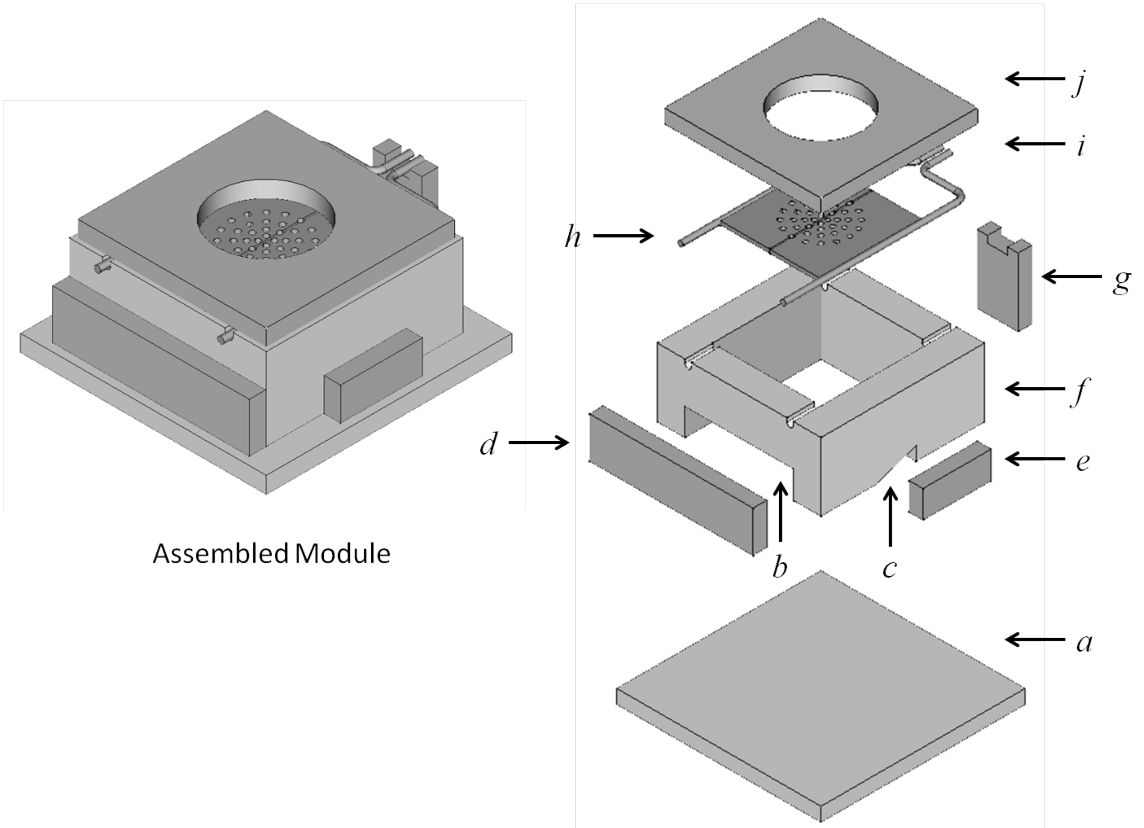

Figure 2. Base Module: (*a*) concrete plinth; (*b*) char clean-out hole; (*c*); wedge-shaped, primary air inlet hole (*d*); char clean-out door; (*e*) primary air regulator door; (*f*) concrete base box; (g) grate handle support block (holds the grate closed); (*h*) metal grate with two hinged flaps; (*i*) grate handles; (*j*) base top plate. All components, except *h* and *i* are made of concrete.

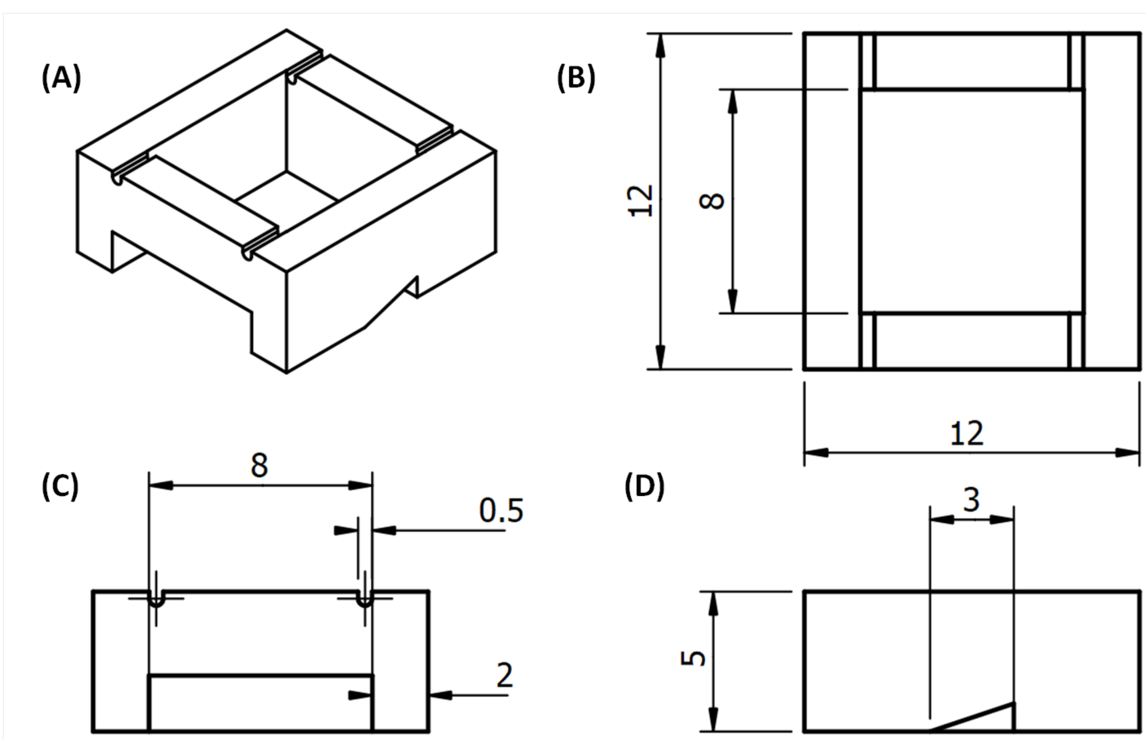

Figure 3. Base module box, component-*f*: (A) isometric view; (B) top view; (C) side view – char port; (D) side view – primary air port. (units: inches)

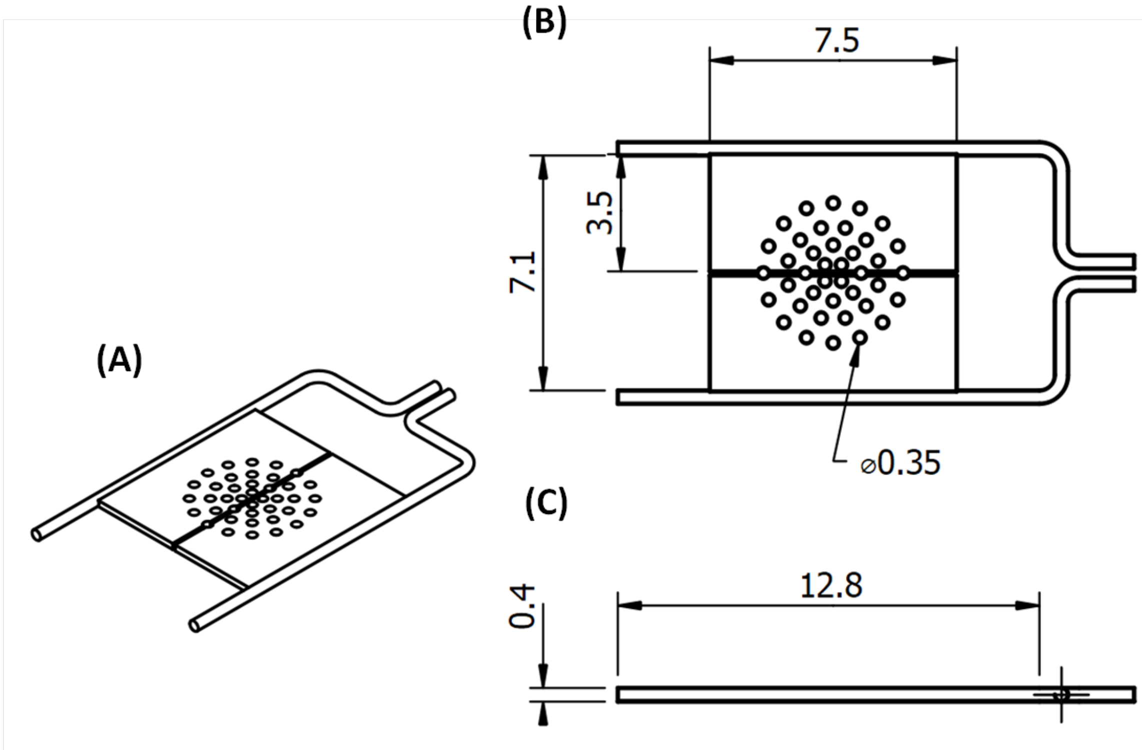

Figure 4. Base Module hinged grate, component-*h* and *i*. (A) isometric view, (B) top view, and (C) side view.

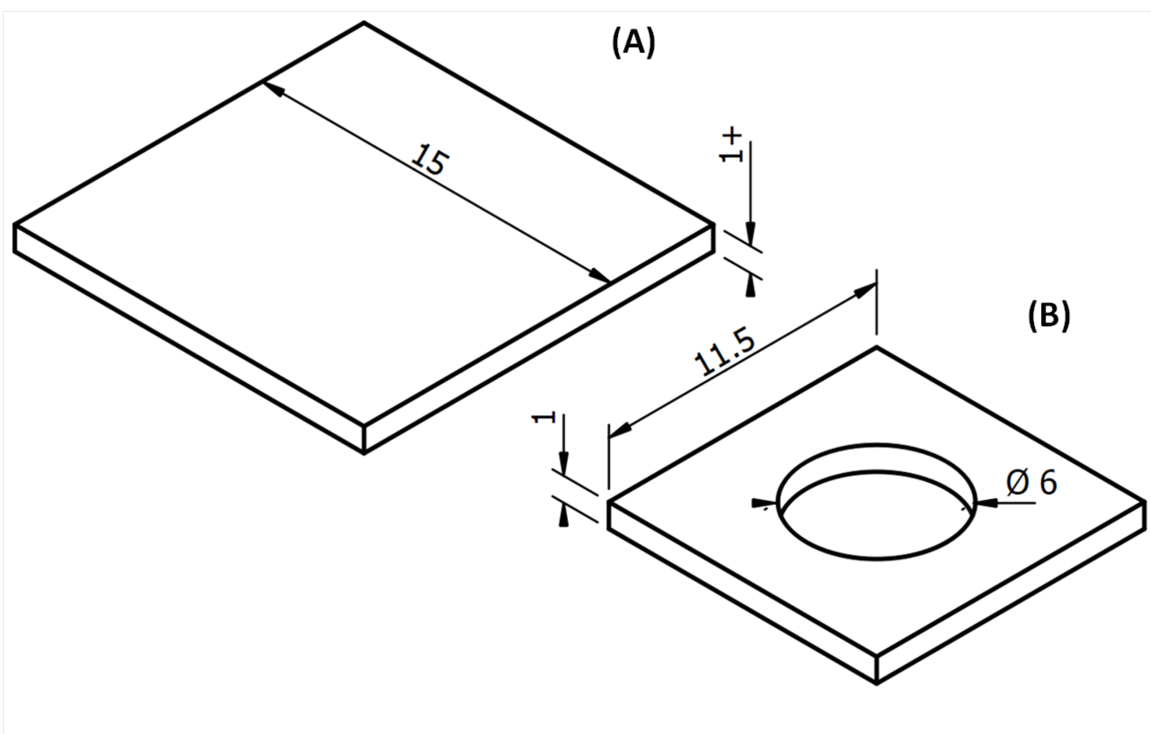

Figure 5. Base Module (A) concrete plinth component-*a*, and (B) concrete top plate component-*j*.

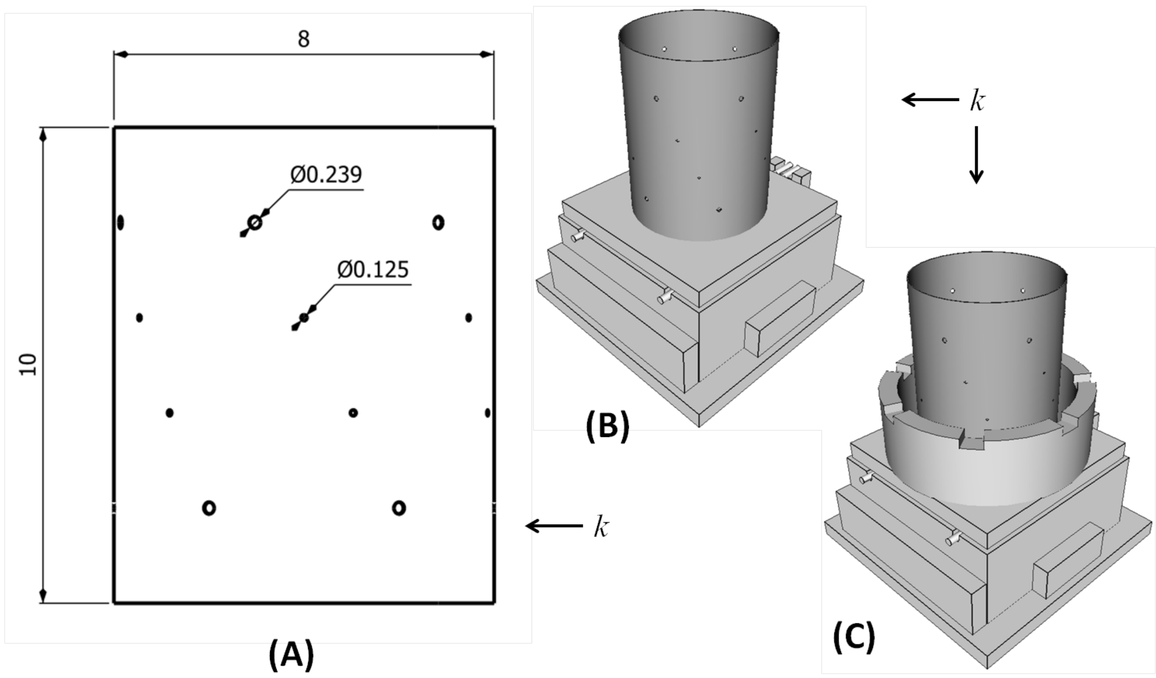

Figure 6. TLUD Reactor, component-*k*: (A) Metal reactor cylinder (8 inches diameter, 10 inches tall) with perforations in the sidewall (4 horizontal rows of 6 holes per row; top and bottom holes are 1/4-inch diameter, middle rows are 1/8-inch diameter); holes in the reactor sidewall stabilize combustion. (B) The Reactor standing on the Base Module. (C) The Reactor surrounded by the lowest section of the Stove Body (see Figure 7, component-*l*). One inch of sand is placed in the space between *l* and *k* to hold the reactor in place and restrict the ingress of air into the bottom of the reactor. (units: inches)

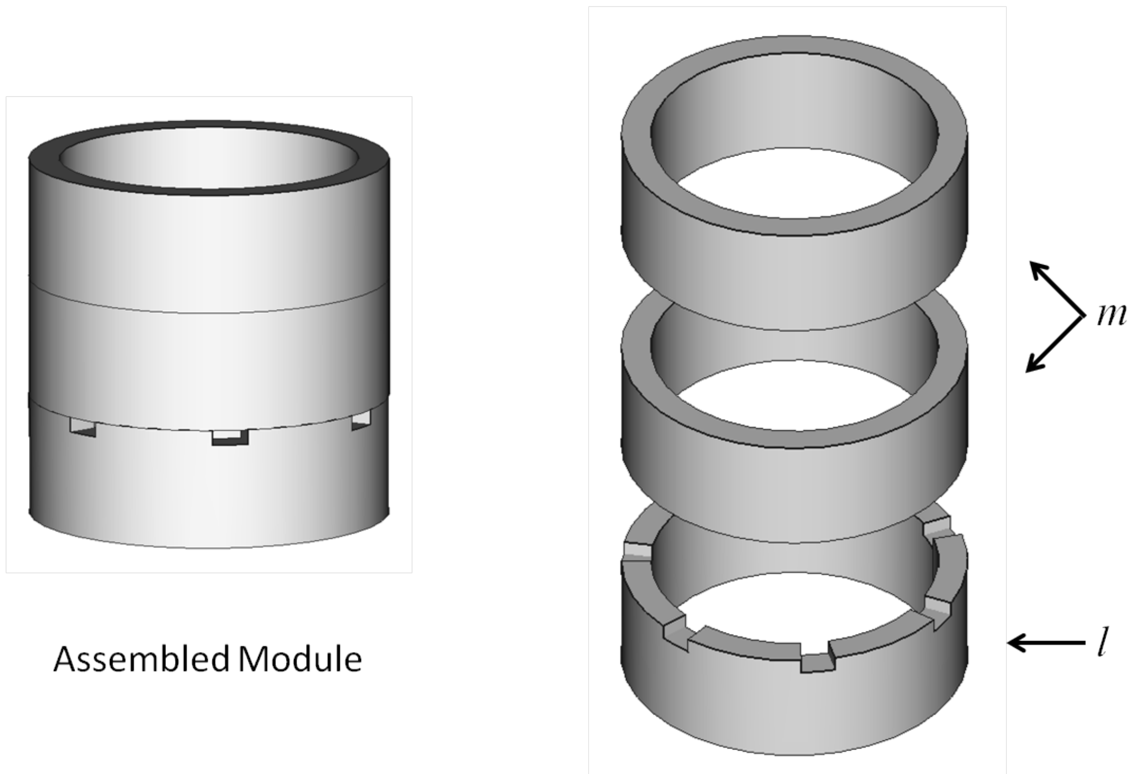

Figure 7. Stove Body Module that supports a cooking surface (Figure 5) and encloses the TLUD reactor (Figure 3). Components: (*l*) concrete base ring with eight gaps for entry of secondary air, and (*m*) middle and top concrete rings. Total height of the stove body is 12 inches.

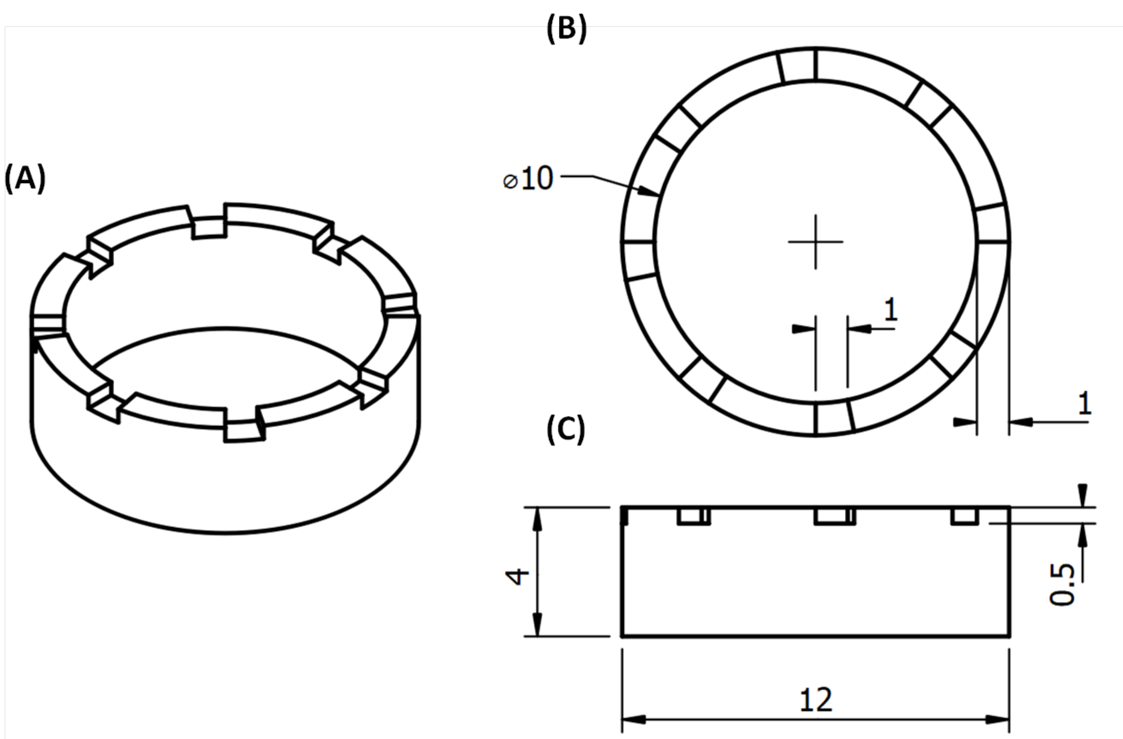

Figure 8. Stove Body Module bottom ring, component-*l*: (A) isometric view, (B) top view, and (C) side view. (units: inches)

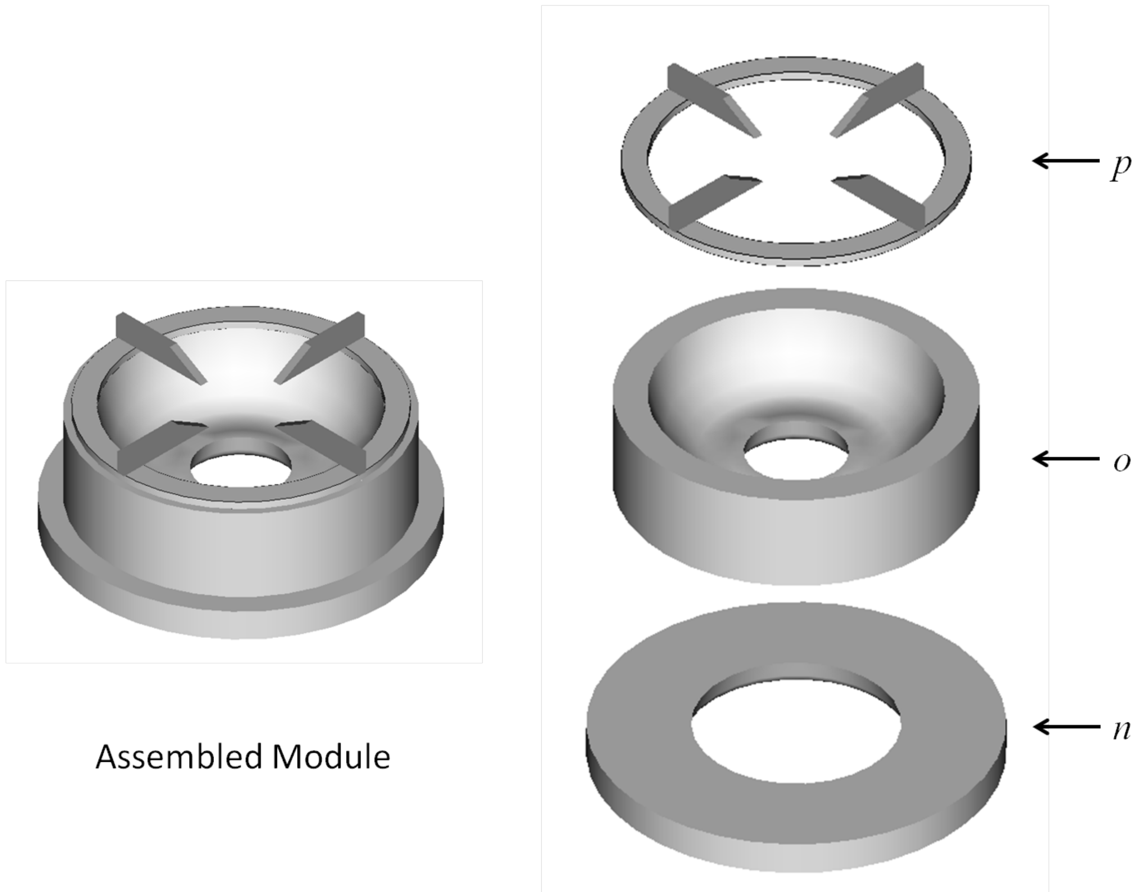

Figure 9. Gas Burner Module components: (*n*) burner support ring, (*o*) nozzle orifice and riser, and (*p*) cooking pot support ring.

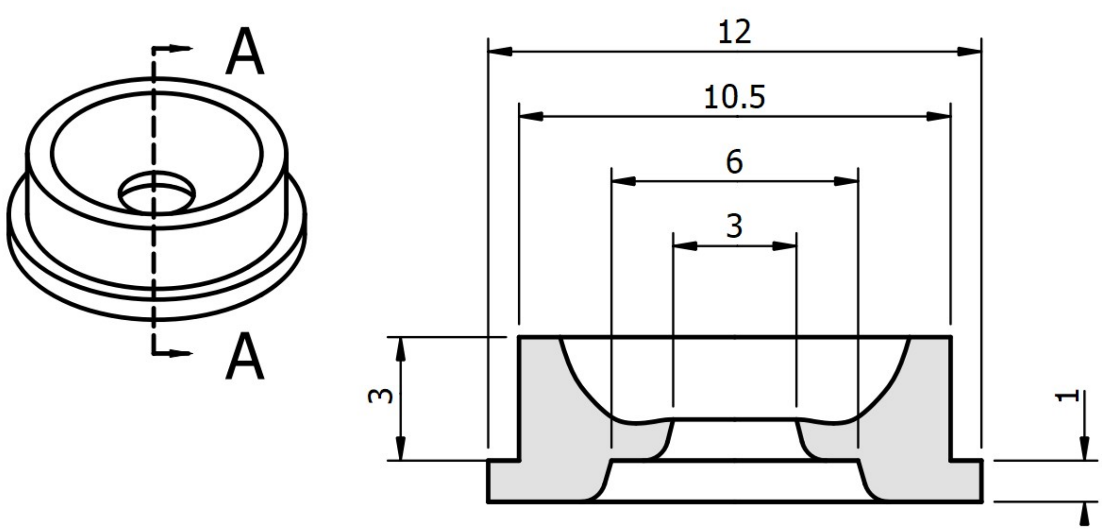

Figure 10. Vertical cross-section through the Gas Burner Module with a nozzle formed by placing the nozzle orifice plus riser (component-*o*) on top of the burner support ring (component-*n*). (units: inches)

ABSTRACT

Our innovation is a top-lit updraft gasifier (TLUD) cookstove/heater adapted for Bangladesh by making components from metal, concrete, and clay. TLUD gasifiers work by spatially separating the primary pyrolysis of wood (or compressed biomass) from the flaming combustion of the volatile 'white smoke' that is released. In this way, the products of primary pyrolysis — char and volatiles (gases, tars, etc.) — can be used for different purposes: the volatiles are burnt at the top of the TLUD for cooking or heating, and the char can be left behind to burn, or can be collected and quenched for use as charcoal or biochar. Compared to traditional '3-stone' stoves, TLUD stoves emit little smoke, and use half as much fuel when not burning the char, and even less fuel when char is burned. Existing TLUD stoves designed in Western countries are made of stainless steel and are light-weight and portable. The TLUD stove described in this patent combined the Western TLUD technology with Bangladeshi heat-resistant concrete to create a robust, semi-permanent installation. There was an imperative to reduce the metal content in stoves since it was expensive when imported. With our innovation, we claim to have adapted existing TLUD gasifier technology to invent (1) a semipermanent TLUD stove/heater with (2) a concrete base for collecting char and regulating primary air, (3) a cylindrical metal rector, (4) a concrete outer stove body that forms a safe, stable cooking platform that protects users from hot surfaces, and (5) a unique concrete-clay nozzle gas burner. (6) The modular architecture of this stove allows for customizing, maintenance, upgrading and recycling stove components. The design can be scaled up or down according to different applications and the firepower required. The purpose of this patent is to present these innovations as *open-source* technology for *free public use*.

PATENTS AND DESIGNS ACT, 1911

N.B. FEE Tk...... where provisional specification has been left with the application. No fee when this Form accompanies the application.

(a) Insert title verbally agreeing with that in the application form.
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(c) Here begin full description of the invention. The continuation of the specification should be upon paper of the same size, on one side only, with a margin of 1.5 inches on the left hand part of the paper. The completion of the description should be followed by the word "I (or we) claim" after which should be written the claim or claims numbered consecutively. The specification and the duplicate thereof must be signed at the end and dated thus:-

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Note.- The claims must be clear and succinct as well as separate and distinct from the body of the Specification, and should form in brief a clear statement of the which constitutes the invention. Applicants should be careful that their claims include neither more nor less than they desire to protect by their Patent. Any unnecessary multiplicity of claims or prolixity of language should be avoided. Claims should not be made for the efficiency or advantages of the invention.