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Systematic and Robust Air Cleanser for Cleaning Pollution Caused by the Rocket Stove

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Key words: Particular Matters (PM), Carbon monoxide (CO), Carbon dioxide, Bi-folded colander framework, knapsack filter, simulated carbon with cellulose nanofiber filter

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Abstract: Cooking in areas with restricted electricity supply where the solely available fuel is wood has become a challenge. More people are recorded every day with respiratory disorders in large part due to smoke-producing carbon monoxide (CO), complex issues (PM) and other extremely hazardous compounds caused by improper combustion in the simplest fuelwood stoves. Hence an efficient, hot burning Rocket Stove has been deployed with fabric filters in the earlier days. However, the rocket stoves with fabric filter remove the PM content that is also in a small amount meanwhile considering CO, CO_2 and other toxins remain the same in the emitted gas/smoke. To tackle these pollution issues, the proposed work innovates a Bi-folded Colander Framework which combines a Knapsack filter and simulated Carbon with a Cellulose Nanofiber filter to purify the exhaust gas/smoke. It is highly sensitive to filter the nanoparticles as well as the toxic compounds that exist in the exhaust smoke. Thus, our proposed methodology effectively reduces the pollutions with the novel framework and enhances the fuel efficiency of the rocket stove.

INTRODUCTION

People in places that do not have access to infrastructure and where there is restricted access to electricity might be a struggle to cook. Wood is the most popular fuel used in many developing countries. The rigorous use of firewood for cooking has highly contributed to increased carbon emissions and deforestation in developing countries. So that, recent technology develops various energy-efficient stoves. The Rocket stove which burns at higher temperatures than the usual wood stove or fire-place is one of the inventions which makes its fatigue much smoother. A racket stove is used to burn straw, dried dung, small rags, etc.[1]. The fact that these stoves have the versatility and combined brutal quality made them a common choice in developing countries. Conversely, the conventional stoves are too smoky and are inefficient, so that, they are replaced with other modern technological stoves (i.e., fabric filter stoves, etc.). Smoky kitchens initiate negative impacts on the health of millions of people[2].

Wood fuel is used globally according to the energy needs and the terms of availability. The risk of acute respiratory infections, chronic bronchitis and obstructive lung disease is increased considerably by prolonged exposure to the pollution of bio-mass[3]. The same happens in developing nations for the use of cookware. Improved cookeries usually fell into three distinct categories: gasified stoves, rockets and forced-air stoves. It suggests further mechanical design changes to prevent the PM as well as CO emission. Also, similar to mechanical design changes chemical changes are employed with the introduction of oxidation catalyst[4]. A significant decline in ambient emissions has been brought on by recent changes in fitting construction by enhancing air supply control in main and secondary combustion chambers. However, during cold-starting and recharging fuel (refueling), the accumulation of particulate matter and emissions will increase. Less emission thus depends on working practices but also the characteristics of fuel. In areas where using these refined fuels is cost-effective[5], the use of pellet ovens, boilers and pellets with correctly specified fuel requirements has considerably improved the environmental impact. However, logs are frequently used and fuel properties are insufficient in terms of the scale and Humidity Quality (HQ) of the fuel. High humidity levels lead to low thermal efficiency and better emissions of contaminants following sluggish and incomplete combustion and this factor has been studied[6].

A variety of studies have investigated the impact of biomass humidity on combustion and pollution. However, it can vary based on the original wood moisture content and the ambient air humidity[7]. For trees, humidity may be lost or extracted from the final grain to maintain an unequal distribution of moisture in the wood[8]. The functional concept of humidity in poorly defined types, such as dried ovine, seasoned and freshly cut is currently in-satisfactory to classify wood as a fire. Any systems have been built where wood is moisture content certified to be below 20% but minimal evidence from actual stove research on its effect are available to date. The picture and scent of smoke curling from a fireplace brings back wonderful memories of heart and home for many people[9]. Wood is a renewable option, as opposed to non-renewable fossil resources including oil, coal and gas. In reality, woodlots are likely to provide an ample supply of fuel in the years to come if firewood is grown sustainably[10]. Smoke which can be a big cause of air pollution and may harm public health and the atmosphere, from burning wood stoves and fireplaces. EPA (Environmental Protection Agency) states that all wood stoves that have been approved in compliance with the 2015 New Source Performance Standards (NSPS) have separately been tested by an authorized laboratory to achieve a maximum particulate emission level of not <4.5 g/h, thereby decreasing the quantity of smoke from wood stoves. Countries that follow EPA standards shall have the correct functioning and use of seasoned firewood in Europe, Canada, Australia, Singapore, etc. It increases burning efficiency and lowers emissions, leads to health safety and environmental conservation and lowers fuel costs[11, 12]. Using a rocket fog stove to reduce the use of fuelwood and increase the performance of the fuel. The rocket mud stove in Uganda was first developed and performed successfully. It was then incorporated into another successful program by GTZ Kenya in 2006. Research in Kenya has shown that stoves are 60% more powerful than conventional cooking methods. It uses firewood more successfully than three stone fires due to its interior architecture. To cook the same amount of food, less firewood is needed. It also discusses the environmental and social ramifications of harvesting wood for electricity.

Knapsack filter: The pneumatic transport systems have two functions of gas-solid separation instruments. Recovering the transmitted content and mitigating environmental emissions in the working material as much as possible. Multiple particle size isolation methods are used: gravity chambers, cyclone separators and filter bag style fabric[13]. If a bulk substance consists of relatively hard and large particles without small dust, the substance may be collected in a clear jar where the solid content comes under the pressure of the bottom of the container while the gas is separated via the necessary ventilation system. When a bulk substance is of smaller particle size, however, the gravitational effect can be needed to improve. The most common way to achieve this is by rotating the gas-solid current to remove the solid particles from the middle of the vortex. This idea is accompanied by a cyclone separator. If particles are good, especially if they are also of low density, cyclone separation can fail to be completely successful and fabric filters may then vent the gas-solid stream. More sophistication in the filtration technique such as the use of water washers, scrubbers and electrostatic precipitators, may be required for materials containing extremely fine particles or dust. The smaller the particles to be extracted in total, the higher the health risks of an effective separation system[14]. Airborne dust usually is smaller than around 10 μm in size and can be found in agricultural conditions. Sections of this scale can be swallowed, consumed by the skin or inhaled into the bloodstream. The former is seldom a significant concern and although skin diseases are not infrequent, they pose the greatest danger to workers in a poisonous atmosphere through inhalation. When inhaled, particles falling within the size range of about 0.5-5 μm will enter the lower lung area in which they are stored. Long-term exposure to such potassium may lead to irreversible damage (pneumoconiosis) of the lung tissues symptomatic of shortness of breath and increased respiratory susceptibility. The details in this booklet relate to the work of the bag-type fabric filter, fabric components, various kinds of bag-type fabric filters, structural requirements, fabric filter management (pulse jet type) and useful words for fabric filters. The filter Knapsack is used to control pollution of particulate matter. The particle-charged gas in the knapsack filter flows through a variety of parallel filter bags which holds the powder residual. The filters are made of 5 filters in this Knapsack. The first step in the design experiments is to determine the flow rate of the filtered gas measured in cubic meters (cubic feet) per minute. The gas volume to be handled shall be determined by the process exhaust but the filter's configuration shall decide the filtering speed or air-to-cloth ratio. The finally chosen air-to-cloth ratio will depend on certain design characteristics, including substrate, fabric fibers, bag-cleaning mechanism[15].

Stimulated carbon with cellulose nanofiber filter: Carbon stimulation filters are commonly used to decrease odors and monitor greenhouse gases and other rising practices. The ambient air passes through the activated carbon filter and returns or releases outside the greenhouse, as seen in Fig. 1. Understanding the fundamental principles of how stimulated carbon filters operate would allow farmers to make better use of technologies with lower overall costs and reliability[16]. Carbon stimulation is triggered by the mechanism known as adsorption when the odor compound is caught in and stored in the stimulated carbon but the adsorption content does not change its dimensions. Adsorption varies from absorption which still extracts material but the swelling occurs. Adsorption and absorption media have fixed space which ensures that they carry too much since they store and do not damage the content extracted from the air. What occurs with absorption is easier to determine since the size increase is proportional to the quantity of substance taken out. With absorption, weight gains exist but it is impossible to calculate because we require other ways to quantify the life cycle of a filter. Activated carbon can minimize odors by having a more comfortable place to live than circulating in the air with the odor-causing material. As the odor compound escapes the environment and is stored within the activated carbon, the adsorbed case is considered a lesser energy state as it is as siphoned into a cavity and cannot escape. New Stimulated Carbon has several unoccupied holes and almost any compound which falls through a hole and is retained. The empty holes fill over time. The adsorbed molecules, kind of like weighing more will move the less closely kept low-energy molecules into molecular musical chairs.

Diverse chemical species may be differentiated with membranes and filters by permitting the movement of some species while others avoid. The membrane selectivity is connected to the membrane material's microstructure and chemistry. To adsorb certain solutes selectively, membranes can be engineered with well-defined pores for the exclusion of dimension and with custom surface chemistry[16].

However, the overall methodologies exhibit some issues in achieving thermal efficiency as well as fuel efficiency that subsequently affects the system performance. Moreover, the number of toxic gases/elements released on the environment is also too high which causes serious health issues to millions of people all over the world. Hence, to overwhelm all such issues and to gain better performance a novelty is required in this field. Therefore, a Bi-folded colander framework is proposed in our work which integrates a Knapsack filter and simulated carbon with cellulose nanofiber filters are used to purify the exhaust gas. Figure 2 shows the before, after filtration condition state of cellulose carbon fiber.

Fig. 1: Cellulose nano-fibre filter with carbon

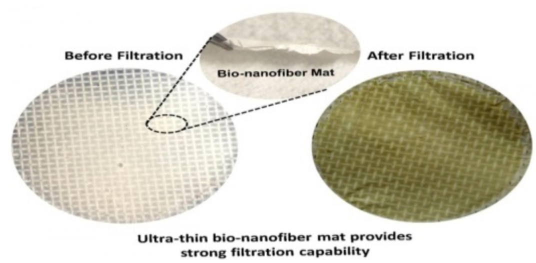


Fig. 2: Illustrating filter condition state

When the filtration medium has been filled and cannot be cleaned in an appropriate way to permit device airflow with the fan on the machine, the majority of dust collector filters hit the end of their life. Nanofiber layer filters last considerably longer than typical product elements due to their performance layer and surface loading characteristics. Longer filter life means less regular procurement of new filters, saving substantial time. Longer filter life often decreases the number of painful down times to sustain filter shifts.

The duration of the filter is a maximum of one year and it can be decided through the filtration of CO, CO_2 from IAP meter.

MATERIALS AND METHODS

Related researches: A. Price-Allison had studied the effect on pollution of the wood-burning domestic stove by the moisture content of carbon. The work analyzed two types of fuel: hardwood beech and softwood spruce. In a recently felled wood, seasoned bodies and ovaries, the moisture content was tested. In contrast with the laboratory study, the result of the humidity calculation system was considered with a commercial electrical conductivity proof moisture meter drying at 105°C in ova. It was found that in some situations the true moisture content can be greatly underestimated by the measure. Correlations of the burning rate and the pollution factors in terms of the moisture content have been developed to form gas and particulate pollutants. To gain details about the organic particles, we also investigated the ratio of black to total carbohydrate (BC/TC). The NOX emissions of this sort of stove relied only on the amount of fuel and nitrogen and not the amount of humidity.

Snider *et al*.[17] has been failed to reach the World Health Organization (WHO)'s 35-µgm-3 interim indoor-air quality target (2.5) for decades-old intervention projects replacing existing biomass stoves with cleaner-burning technologies. Many of the characteristics of the constant use of wood stoves and the low air quality of the outer world are also due to these causes. In 150 rural households in Sichuan, China, they assessed 496 days of real-time use of stoves in parallel with air and outdoor emissions (PM2.5). Indoor PM2.5 is quantified for the influence of the trends of stoves and the outdoor temperature of the air. In southwest China, they estimated also that the transition from conventional to clean fuel stoves through defined exposure-response relationships could lead to cardiovascular mortality avoided. In homes using both wood and clean fuel furnace, the mean daily PM2.5 was maximum (122 µgm-3), led by the sole use of timber fuel furnace (106 µgm-3) and cleaner fuel furnace. Wood fireplace emissions of PM2.5 during combustion were proportionally higher and the duration of use of fireplaces was not related to increase indoor PM2.5. The WHO air quality target was reached only 24 percent of days with exclusive clean fuel stoves while this figure grew to 73% after the outdoor exposure to PM2.5. The reduction of exposure to PM2.5 was estimated at 48,000 premature deaths annually in southwest China, with larger cuts if the outdoor PM2.5 locally is also limited, by exclusive gas or electrical stoves. Since, their usage is exclusive and air quality outside is reasonably minimal but can still have some health conditions, clean stoves and measures to reduce the volume of indoor PM2.5 to the objective of the WHO is doubtful.

De la Sota *et al*.[18] the efficacy of a stove intervention program to decrease indoor pollutant levels in a rural village in Senegal was measured in a cross-sectional analysis. Results indicated that in this region the household air pollution is primarily caused by cooking. The construction of an advanced rocket stove locally manufactured led to a substantial reduction of the overall amount of thin and ultra-fine particulate matter as well as of CO in conventional stoves (75.4, 30.5 and 54.3%, respectively) but also increased indoor BC concentration (36.1%). These findings will have a beneficial impact on the health of the enhanced cookstoves but not all the tracked contaminants. This indicates that the atmosphere and the health consequences of stoves do not necessarily coincide and highlights the significance of all dimensions. The co-benefits on combating climate change should be viewed as rising alternate cookstoves aimed at reducing BC emissions. Findings also indicate that effective measures aimed at improving the quality of household air in Senegal should include ventilation activities and building materials in addition to the swapping of the pollution source (such as cookstoves and/or fuel). The majority of the improved cookers (40 out of 50) distributed in 2012 were fully or partly disused in the rural village surveyed which demonstrates that the acceptance and continued usage of stoves among families are possible and difficult to introduce improved cookery projects. Therefore, effective methods for improving household air quality should provide information on proper ventilation and adequate cooking education in Senegal and other populations in sub-Saharan Africa.

Press-Kristensen *et al*.[19] in small stoves and boilers, domestic wood (and coal) heating releases nearly 50% of the cumulative emissions of fine particulates and black CO_2 into Europe. Many tests have also reported that ultrafine particle emissions from residential heating are important. Particulate filters have also lowered pollution in other industries. Filters or other flue gas cleaning devices for small stoves or boilers are not yet standard equipment. While modern stoves and boilers pollute much more than other sources of heat and road traffic. It was targeted in a bag filter suitable for small stoves and boilers to explore particulate removal of an electrostatic filter and a condensing flue gas system. This research investigated the replacement of electrostatic filters and a gas condenser flue system with a bag filter, in two filter systems that are adapted for stoves and boilers. Dilution tunnels have been assessed to have condensates. Using ultrafine particle (PM0.1) P-tracks and conventional particle mass (quartz filters) selection for fine particles (PM2.5) were measured. Measurements were carried out. The mass of particles obtained was measured and analyzed for Organic Carbon (OC) similar to black carbon (soot). Measurements before and after all filter systems were used to assess removal efficiencies. The two filters tested effectively recover particulate matter, finer particulate matter, primary carbon and organic material. The bag filter is highly efficient and ultrafine particle removal has also been demonstrated.

Kantova *et al*.[20] has recommended separating particles until they leave the air due to their adverse effect on the well-being of humans. Some tools can distinguish these particles. Yet integrating them in a small heat source can be difficult for finance and also include complicated maintenance. It is necessary therefore, to search for alternatives for simpler maintenance and thus fewer financial challenges to minimize the production of particulate matter. This study addresses the simulation of the flux of particles by using blisters put in the wood stove flue tract. CFD simulations demonstrate the effect of baffles. Air safety includes a decrease in particulate matter. Different forms may be used to remove particulate matter. But often separators are financially complicated and also repair challenging. Therefore, more useful alternatives must be found. This study deals with particulate matter flow analysis by using blankets put in the wood stove flue tract. It was observed with CFD simulations and analyses of their effect. For larger particles caught, the baffles were successful. In the movement of flue gas, there had been a greater number of smaller particles.

Makonese and Bradnum[5] the concept based on the original Aprovecho rocket shelter (RS1) was found during the field experiment to be difficult to light and the flame cannot be retained for cooking. The stove was inability to hold fire whilst cooking was that the air flowing under the grid was obstructed with ash, effectively robbing the burning region of oxygen after a half-hour of ignition. When the flame was smoke, it was insecure to clear the cup from the combustion chamber.

Paulsen *et al*.[22] introduced a rocket style cookstove, using potassium oxide as a catalyst. Further to boost carbon monoxide oxidation operation, doping potassium titanite with copper or cobalt. It reduces both the PM and carbon monoxide emission below the recommended limits when compared with an empty stove and a three-stone fire. However, several health effects are created with this catalytic rocket stove.

Thus, from the above data, it is clear that the prior methodologies face some issues with the conventional rocket stoves. Reduce air pollution exclusively and outside significantly but it also leads to some cardiovascular disorders. Fernando *et al*.[23] is highlighted about smoke compounds which leads to an unsafe health issue, ends to deal with these issues an ecofriendly stove technology, that prevents the pollution caused by the emission of exhaust gas has to be innovated.

McCarty *et al*.[24] an initial report was examined for three types of rocket stoves: a single kettle, a twin and a double chimney fireplace compared as well to typical fireplaces in Tamil Nadu, India. Also, the following studies are provided. The stoves have been tested by using the controlled cooking test to assess the consumption of gasoline, carbon monoxide and emissions of particulates whereas local cooks make widely prepared foodstuffs. Aprovecho Research Center used portable pollution control instruments for monitoring pollution both from the facility and on the ground. A good experience was the controlled cooking test sequence on the pilot stoves in India. The findings demonstrated considerable fuel and pollution savings and generally in line with the requirements of the nature of the laboratory. The portable pollution system performed well and the cooking process was easy to use and resistant. As this technique reduced most of the emissions indoor but polluted outdoor.

Thompson *et al*.[25] Examined influence on low-level (LBW) exposure to reduced wood smoke during pregnancy is characterized as a birth weight in RESPIRE (Randomized Exposure Trial for Indoor Emissions and Respiratory Effects) for Guatemalan children which is focused on World Health Organization (WHO). In contrast with those using open fires, pregnant women using chimney stoves were 39% less prone to carbon monoxide. At 22.4%, the LBW prevalence was high. The average number of children born to mothers who used a stove is 89 g higher (CI 95%) relative to children whose mothers used an open fire after the maternal change, diastolic blood pressure, gravity and birth season. In contrast to open-fire consumers, the modified OR for LBW was 0.74 (95% CI, 0.33-1.66). In infants born during the cold season (after the harvest), the average birth weight of 296 g was above other infants. The unusual results may indicate the role of maternal nutrition in the weight of birth in a poor environment which was not expected to occur. A fireplace decreased the intensity of wood smoke and was related to a lower incidence of LBW. The approximate impact was consistent with previous research but not statistically significant. It eliminates 39% of CO from pollution by this technology.

Novel Bi-folded colander framework: The rocket stove is a clean-burning stove that can use thin sticks to make fuel-efficient. This makes the Rocket stove more effective than open fires and lowers long-term home costs by using less firewood. The potential of rocket stove to use thin, dry branches negates the need for progressively damaging environmental impacts with the use of charcoal and deforestation. Rock stoves have an enclosed combustion chamber that helps them to direct the heat where it is required (e.g., in the cooking pot). During and after use, it is often pleasant to handle. Rocket stoves make it easier, safer and faster to cook with fire than with open fires. They start sooner, need little effort and can satisfy domestic and small/large business cook's unique specifications. Rocket stoves minimize the time required

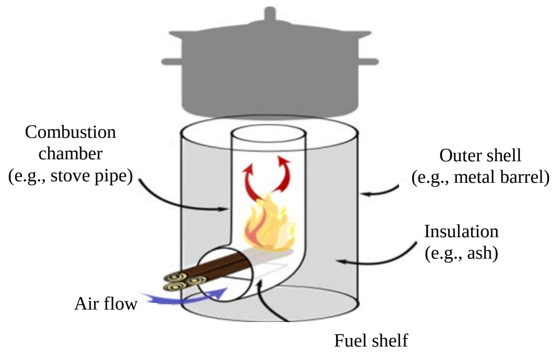


Fig. 3: Simple design of rocket stove

to start a stove and cook food because their fuel efficiency is excellent. A person must not blast air onto the stove to ignite the fuel. The fire will burn constantly after the fire has been ignited unless firewood is prevented on the fireplace. The cocktail stoves cook a certain amount of food in half the time relative to an open fire of three stones[21].

The rocket stoves in many areas across not just Zanzibar but across East Africa as a whole where wood fuel is costly and/or difficult to obtain, are perfect for domestic and business cooking and grooming. In the isolated combustion chamber of the cockpit, the firewood wood is burned Fig. 3. The basic "elbow" type makes good airflow and controlled use of firewood resulting in incomplete combustion and effective use of the resulting temperature[21] (including hazardous smoke).

In rocket stove is the high temperature reached high-efficiency stove. Wood is the fuel of this stove. Burning the wood at the bottom of the stove; the heat will flow to the top of the stove in Fig. 2. Wood burning contributes in form of smoke produced by the burning of wood to pollute the environment. Smokes are emitted and can also pollute the air inside the house when not sufficiently ventilated, allowing smoke to collect in your rooms in winter, particularly in the case of smoke from outside. Wood and coal flames but also daily practices such as burning candles, automatic toasters and gas cooking, contribute to combustion. Combustion emits microscopic particles that will add dusting and vacuuming and also gasses that contain carbon dioxide (CO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). Volatile Organic Compounds (VOCs) are compounds used in many different materials. VOCs are organic substances. They are produced when cooking and using heating appliances such as wood burners and non-electric space heaters. VOCs, evaporate into the air at room temperature, forming vapors that we breathe, so that, we used the proposed methodology in Fig. 4.

Design of rocket stove: Take the cupboard height which is used for cooking as seen in Fig. 5 to decide the position

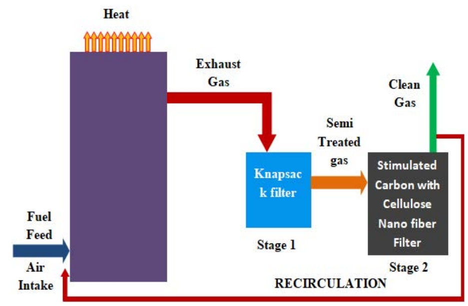


Fig. 4: Proposed methodology

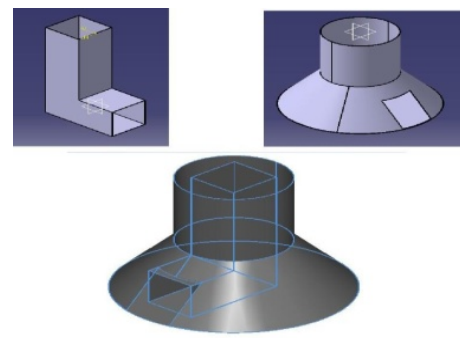


Fig. 5: CATIA Model of cook stove-2

of the stove. Therefore, the ability of the cup is the first thing to assess. This handbook details the measurements of 3 sizes for the pots to be used for cooking the burner. The measurements should be changed differently for larger cooking pots.

Design parameters

Combustion chamber/elbow dimensions:

- Height of elbow = 420 mm
- Elbow at inlet = 120 mm*120 mm
- Diameter of outer casing = 240 mm
- Outer casing diameter of = 500 mm
- Thickness of material used = 1.2 mm
- Material for setup = mild steel
- Insulation material = Siporex
- Wood section = 120 mm*30 mm* 30 mm
- Weight of setup = 8.778 kg

The efficiency of a stove is normally defined by the heat transfer ratio of the fuel supplied to the cooking medium to heat. A variety of common techniques, including constant heat output, will determine the performance of the stove. Constant method of rising temperature, constant-time method and Water boiling test. Of all, the most widely employed water boiling procedure seems to be; this research procedure is also used in the present analysis (Fig. 6).

Fig. 6: Weight of cookstove

Fig. 7: Manufacturing of skirt for stove

Design of skirt for cookstove: To maximize heat transfer and fuel efficiency as seen in Fig. 7, the stove is filled with an L-shaped elbow and pot "skirt". For the inner chimney, the gas from the fire is drained and propelled. Then these gases are pushed into the skirt around the cooking pot.

Figure 7 shows the manufacturing of a skirt. The design and gap calculations for the skirt were done based on Aprovecho design guidelines as shown in Fig. 8. Based on that skirt is manufactured and WBT was conducted:

$$\text{Pot diameter} = \frac{\text{Circumference}}{3.1416} = 17.5\text{ cm}$$

$$\text{Area of combustion chamber}: = 3.14$$
$$(\text{Diameter of Riser}/2)^2 = 213.82\text{ cm}^2$$

Gap A (inner edge):

$$\frac{\text{Area of combustion chamber}}{(\text{Diameter of Riser*3.1416})} = 3.14\text{ cm}$$

Gap B (Outer edge):

$$\frac{\text{Area of combustion chamber}}{(\text{Diameter of outside bucket*3.1416})} = 2.83\text{ cm}$$

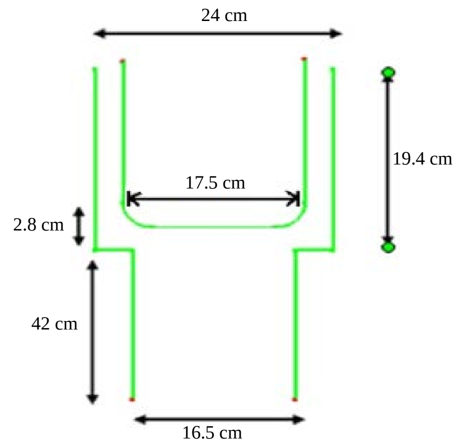


Fig. 8: Line diagram of skirt showing outlook around the pot

Gap C (Below outside edge of the pot):

$$\frac{(\text{Area of the combustion chamber})}{(\text{Pot below circumference})} = \frac{(213.82)}{54.978} = 3.88\text{ cm}$$

- Gap D (Outside of pot and inside of skirt) = 75% of C = 2.91 cm
- Determine desire outside diameter of skirt
- Diameter of skirt = (Dia. of pot)+(2*gap D+rim overlap+skirt thickness) = 17.5+(2*2.91+1.5+1) = 30.82 cm
- Length of skirt
- Gap between surface and top of skirt = 4 cm
- Pocket depth = 1.3 cm
- Length of skirt = (Pot dist.)-(Gap above skirt)+Gap C+2*(Pocket Depth) = 19.4 cm

Design of exhaust pipe

Calculation of velocity of exhaust gas: The following expression can be integrated and resolved for the pace of exhaust piped entry to combine continuity, complex and ideal gas equations:

$$v = \sqrt{\frac{2\text{ gh}\left(\frac{T_1 - T_2}{T_2}\right)}{\left(\frac{P_1}{P_2}\right)^2 - 1 + \frac{FH}{4\text{ D}}\left(1 + \frac{P_1}{P_2}\right)^2}}$$

For inputs:

- The velocity of exhaust gas V = ?
- Height of the upper skirt h = 19.4 cm
- Chamber diameter D = 16.5 cm
- Initial temperature T1 = 100°C
- Final temperature T2 = 95°C
- Atmospheric pressure P2 = 1013.25 Pa

- Acceleration due to gravity g = 0.981 cm sec^{-2}
- Relative ideal gas constant R = 287 J/kg-K
- Force F = 0
- Substituting all the values in the above equation, we get
- Velocity of exhaust gas V = 1.4 cm sec^{-1}

Calculation of flow rate:

- Q = (A2-A1) V
- Q = Flow Rate of exhaust gas (cm sec^{-3})
- A1 = Area of the combustion chamber (cm^2)
- A2 = Area of the upper skirt (cm^2)
- V: Velocity (cm sec^{-1})
- Q = (302.5-213.5) *1.4
- Q = 124.6 cm sec^{-3}

Calculation of exhaust pipe diameter:

$$D_{EXT} = \sqrt{\frac{4\times \text{flowrate}}{3.14\times \text{velocity}}} = \sqrt{\frac{4\times 124.6}{3.14\times 1.4}}$$

- DEXT = 10.6 cm
- The diameter of the exhaust pipe is 10.6 cm
- The height of the exhaust pipe that has to be fitted in the stove is ½ of the height of the upper skirt
- Height = ½*19.4 = 9.7 cm

Calculation of burning capacity rate: If the manufacturer does not specify the fuel burning rate, the cooker shall be run by the system listed below and used for the assessment of the cooker burning power. Stack the fuel in honeycomb mode in the combustion chamber for continuous feeding of the form cookstove up to 3/4 of the height or on the manufacturer's prescribed template.

Weigh the cookstove with fuel, let the mass be $m_1$kg. Sprinkle 10-15 mL of kerosene on the fuel from the top of the Cookstove /firebox mouth. After the half, an hour of lighting weigh the stove with fuel residues again and let the mass be $m_2$kg. Then, calculate the burning capacity of the Cookstove as heat input per hour as follows:

$$\text{Burning capacity rating} = 2\ (m_1\text{-}m_2)\ \text{kg h}^{-1}$$

$$\text{Heat input per hour} = 2\ (m_1\text{-}m_2)\times \text{CV kcal h}^{-1}$$

Where:

m_1 = The initial mass of the Cookstove with test fuel in kg
m_2 = The mass of the Cookstove with fuel residues, after burning the test fuel for half an hour in kg
CV = Calorific value of fuel in kcal/kg

Table 1: Wood sample weight

No.	Weight of wood before drying	Weight of wood after drying
1.	80.0	76.8
2.	82.0	76.2
3.	82.1	78.2
Total	244.1	231.2

Calculations for without insulting liner material (Table 1)
Calculations for moisture content test:

$$\text{Moisture content\%} = \frac{\Sigma(W-d)}{\Sigma d}100$$

Where:

W = Wet weight of wood
d = Weight of dry wood (after weight)

Therefore, % moisture content:

$$\frac{(244.1-231.2)}{231.2}100 = 5.57\%$$

Calculation of burning capacity rate:

- m_1 = Initial mass of cook stove with test fuel = 8.778+(76.8+76.2+78.2) = 9.0092 kg
- m_2 = Final mass of cook stove after burning = 8.778+ (0.0341) = 8.8121 kg
- Burning capacity rating = 2 (m_1-m_2) kg h^{-1} = 2 (9.0092-8.8121)
- Burning capacity rate = 0.3942 kcal h^{-1}. Heat input per hour:
- Heat input per hour = 2 (m_1-m_2) CV kcal h^{-1} = 2(9.0092-8.8121) 4302.103
- Heat input per hour = 1695.88 kcal h^{-1}0.< 2000

From the above calculations as per BIS 13512, pot selection dimensions will be as follows Table 2. From the above calculations as per BIS 13512, pot selection dimensions will be as follows:

- Vessel diameter = 180 mm
- Vessel height = 100 mm

Combustion chamber: A combustion chamber is an enclosed space inside of a combustion Stove in which a fuel and air mixture is burned in Fig. 9. Where wood is burnt and changed to hold the flames. Burning fuel releases a gas that increases in temperature and volume[26]. When you heat a gas, the atoms in the gas start bouncing off each other with more energy and vigor. The hard bouncing causes them to get thrown out farther and the whole gaseous cloud expands.

Thermal insulator: The method of insulation of heat transfer between the materials which are in thermal

Table 2: Aluminum vessels for thermal efficiency

Heat input rate kcal/h	Vessel dia (Ext) mm (±5%)	Vessel height (Ext) mm (±5%)	Total mass with Lid gm (±20%)	Mass of water in vessel (kg)
Up to 2000	180	100	356	2.0
2001-2800	205	110	451	2.8
2801-3200	220	120	519	3.7

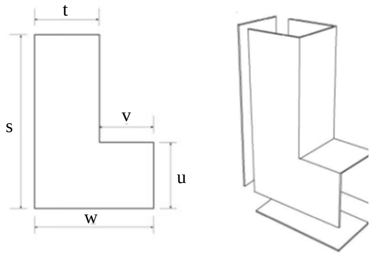


Fig. 9: Combustion chamber

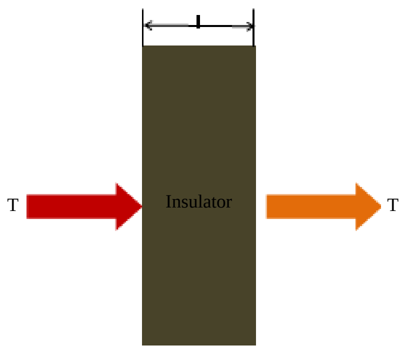


Fig. 10: Heat flow of insulator

contact is the method of isolating material[27] as shown in Fig. 10. Its thermal conductivity tests thermal insulation. For thermal insulation, low thermal conductivity materials are used. Density and heat capacity are important properties of isolating materials in addition to thermal conductivity. The thermal insulators are used to reduce the heat loss of the stove. In this project, used Ceramics Thermal Insulation.

Discussion over design (Fig. 11)
Lower pipe
Purpose:

- As the end of the exhaust pipe is fitted into the lower pipe
- Now, the lower pipe is attached to box 2

Function:

- The function of the lower pipe is to allow the passage of exhaust gas for further proceedings
- The length of the pipe is 60 cm
- The diameter of the pipe: 10.6 cm
- Fitted at 8.1 cm height from the origin of box 2. (x, y, z) (8.1, 0, 8.1).(2.8+1/2 dia)

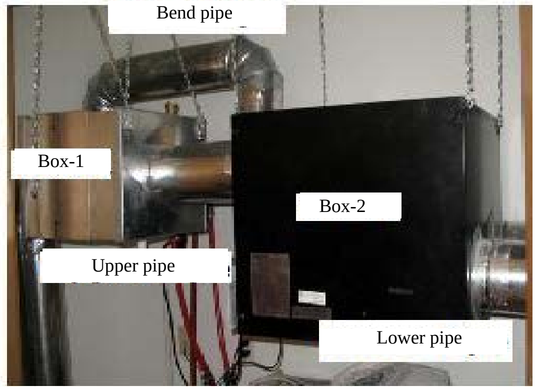


Fig. 11: Design parameters

Box 2
Purpose:
The purpose of the box is to carry out the knapsack filter process. As it is a closed system which doesn't allow any air to enter.

Function: The function of this box is to carry out the first stage filtering process (knapsack filter). So, in the first stage particular matter has been removed. It is used for particulate emissions control, the particle-laden gas enters into the box 2, in which several filter bags placed in parallel, leaving the dust retained. In this, it consists of 5 filters. That filter has been made in Polyester. Now, the semi treated gas passes to the box 1 via. the upper pipe. Size of the box is 60×60×60 cm.

Upper pipe along with bend pipe
Purpose: The upper pipe is mainly used for the transmission of exhaust gas from box 2 to 1. As the pipes are in cylindrical shapes to avoid losses such as edge loss, contraction losses.

Expansion losses
Fitting calculation: As it is fitted over some height in box 2 as the reason behind is for avoiding pressure loss and to get a proper suction to proceed further. The length of the pipe is 60 cm. Dia of the pipe is 10.6 cm. (Same as the lower pipe to avoid sudden losses mainly pressure).

The fitting of the pipe is at the height of -8.1 cm from the origin of box 2 (x, y, z) (-8.1, 0,-8.1). The bend pipe is fitted for a bypass of exhaust gas; it is connected with the upper pipe at a distance of 8.1 cm from box 2. The bend pipe is being tilted to a 45° to avoid losses. Now, the pipe is fitted over the upper portion of box 1 at a distance of (x, y, z) (-8.1, 8.1, 0).

Function: It is a communication way for the semi treated gas that has to be further processed into box 1 for further filtration. The diameter of the pipe is the same as the exhaust pipe that is 10.6cm.

Box 1

Purpose: Box 1 mainly carry-outs the stage 2 process which is mainly used for filtration of chemical compositions like CO, CO_2 and hydrocarbons.

Function: Filtrations are mainly performed using a cellulose nanofiber filter. So, this cellulose will act as a catalyst for the removal of carbon contains from the gas. So chemical reaction takes place inside it which is discussed in the below sections (3.2.2).

So, now the gas coming out is free from chemical compositions and it has been recirculating further for the process of efficient execution. Size of the box 50×50×50 cm. Box 1 is fitted slightly higher than box 2 (height gap of 5 cm). The upper pipe will be fitted at a height of 14.1cm from the origin of box 1 with 5+2.8+ (1/2*dia).

Recirculating pipe: The pipe running below the box 1 is used for the recirculation of clean gas that contains oxygen for the process, to obtain good fuel efficiency. The diameter of the pipe is 10.6 cm.

Fitting of the pipe is done at a height of 8.1 cm from the bottom origin (x, y, z) (0, 8.1, 8.1). The pipe will be connected with an elbow of 450.

Outer Shell: It is defined as the outer layer of the Rocket stove. It is used to cover the insulation.

Firewood tray: It is used to holding the wood to feed the fuel to the combustion chamber.

Exhaust pipe: It is used to exit the flue gas (Fig. 12).

Bi-folded colander framework: As by the name Bi-folded colander, the framework deals with two filters: Knapsack and simulated carbon with cellulose nanofiber filters to perform effective removal/filtering of PM, CO and other toxicities from the emitted gas/smoke. Initially, the smoke is allowed to pass through the knapsack filter, where the particular matter gets filtered/removed. The smoke is then moved via simulated Carbon with Cellulose nanofiber filters. Here, the major reduction process is carried out, i.e., the toxic chemicals that exist in the emitted gas/smoke are filtered and are removed. Finally, the smoke with reduced toxicity is allowed to exhaust. The brief narration regarding the functioning of filters are given as follows (Fig. 13):

Fig. 12: Real-time proposed rocket stove

Fig. 13: Design setup

Design of knapsack filter: The knapsack filter is used to control pollution of particulate matter. The particle-charged gas in the knapsack filter flows through a variety of parallel filter bags which holds the powder residual. The filter is made of 5 filters in this knapsack. This Polyester filter was made. The first step in the design experiments is to determine the flow rate of the filtered gas measured in cubic meters (cubic feet) per minute. The device exhaust specifies the amount of gas to be handled but the filtering speed or air/tool ratio is determined by the configuration of the filter supplier[28]. The air-to-tubing ratio finally selected depends on unique design factors, including fabric type, fabric fabrics, bag cleaning mechanisms and the total number of bags, to name a handful. The concept function is seen in Fig. 14. The following considerations should be included in a careful analysis of the filter architecture.

For deciding the substance that is to be used, the physical and chemical properties of dust are extremely significant. This includes dust size, form, shape and density, medium and maximum quantities, chemical and physical properties such as abrasively, explosive properties, electrostatic loading and agglomerating tendencies. If the dust has an electrostatic charge, it must also be able to clean the chosen fab without destroying it, so that, the full component selection can be given.

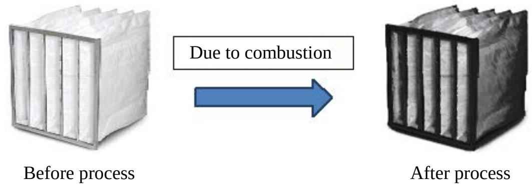


Fig. 14: Knapsack filter

For successful filter design, the prediction of gas flow is essential[29]. Before the final design, it should be calculated the average and maximum flow rate, temperature, water content, chemical properties such as dews, corrosiveness and combustibility. The industrial facility might conduct a stack test to evaluate process gas stream properties if the filter is built on existing supply. Although, data from a similar plant or project can also be used while the filter is being mounted on a different site, it must be constructed conservatively (a large number of bags, additional compartments, etc.). High dust concentrations are often treated thru a filter along with a cyclone pre-cleaner rather than by creating a larger filter. Once the properties of the gaseous stream are known, developers may decide if extras such as shell separation, special bag processing or corrosion-proof coatings on structural components are needed for the filter. Figure 14 states the condition state of the knapsack filter.

Style characteristics of the fabric would then be picked. The engineers of the design must identify: woven or felt filters filter width, fiber size, the density of fiber, filter treatment, resin and heat setting and special coatings. The filter option and special care of the filter can be better rendered after the properties of the dust and gas stream have been calculated. The better option may be to use woven glass bags which are covered with silicon graphite or other lubricant substance like Teflon when, for example, the process exhaust is at 400°F (204°C) with a reasonably large concentration of sulphur oxide.

Design of stimulated carbon with cellulose nanofiber filter: The simulated carbon with cellulose nanofiber filters is mainly containing two types of filters. They arranged parallel to each other.

Simulated carbon filter: Simulated carbon can be extracted and processed in various manufacturing processes from several different sources. The used raw materials, virtual processes and parameters of the process determine the physical characteristics and quality of the resulting carbon. The alteration of these activation properties influences the distribution of porosity and the pore volume of carbon. The purpose of this study is to detail a mass balance for simulated carbon processing and to establish rapid screening strategies to track and

Fig. 15: Stimulated carbon with cellulose nanofiber filter

compare the effects on this processing process of various precursor materials and chemical reagents as well as process variables. Activated carbon is characterized as a carbonaceous, highly formed substance with a broad internal surface.

Porous structure comes from raw materials manufacturing with high-temperature reaction. It contains 87-97% carbon but also other elements according to the manufacturing system used and the raw material it extracts. The porous structure of artificial carbon helps it to adsorb liquid and gas materials. It usually has a pore capacity of between 0.20 and 0.60 cm^3/g with a diameter of up and 1 cm^3/g. Usually, its surface area is between 800 and 1500 m^2/g[2] but reaches 3,000 m^2/g. The surface area often includes micro-spores with pores with less than 2 nm in diameter[3]. The 2 these favorable characteristics make simulated carbon a common absorber for many applications, processed to render carbon extremely porous for absorption or chemical reactions with a wide surface area. Used typically with certain airborne contaminants in air purifiers with odor absorption. Cellulose nanofiber filters are a very sensitive filter to filter the nanoparticles (Fig. 15).

Working process: In rocket stove is the high temperature reached high-efficiency stove. Wood is the fuel of this stove. Burning the wood at the bottom of the stove; the heat will flow to the top of the stove. Wood burning tends to pollute the air by releasing smoke as wood is burnt. Smokes are emitted and can also pollute the air inside the house when not sufficiently ventilated, allowing smoke to collect in your rooms in winter, particularly in the case of smoke from outside. Wood and coal flames but also daily practices such as burning candles, automatic toasters and gas cooking, contribute to combustion. Combustion emits microscopic particles that will add dusting and vacuuming to this and also gasses including carbon dioxide (CO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). VOCs are compounds used in many different materials. VOCs are organic substances. They are produced when cooking and using heating appliances such as wood burners and non-electric space heaters. VOCs, evaporate into the air at room temperature, forming vapors that we breathe, so that, we used the proposed methodology.

Exhaust gas is flowing through the exhaust pipe to the knapsack filter. For particulate pollution control applications, knapsack filters are used. Knapsack filters can be equipped to capture particles with a control efficiency of 99.9% across the sub-micrometer scale. Often they are used to extract particles from exhaust air streams produced by cooking processes where clean air is returned to the next purification phase. Filtering of fly ash in fossil-fuel boilers, urban and hazardous waste incinerators as well as a variety of other industrial processes has been performed by Knapsack filters. The rapid growth in the usage of particulate control knapsack filters has been assisted by the shift by the EPA to an average aerodynamic diameter of 10 micrometers (PM10) from the term “absolute particulate matter”.

After that, the exhaust gas flow to the next level filter is called simulated carbon with the cellulose nanofiber filter. In this study, they had two filters like carbon filter and cellulose nanofiber filter. Although, activated carbohydrates can adsorb hundreds of chemical compounds and smells, they cannot eliminate all. Carbon is not particularly useful until such popular chemicals such as formaldehyde or sulphide are extracted. Carbon may be impregnated with potassium iodide or mixed with active alumina to improve absorption properties in these circumstances. This ensures that all the small areas and holes inside the charcoal contain an additional substance which now binds to and neutralizes the formaldehyde or the airborne hydrogen sulphide rather than charcoal, VOCs, Nitrogen Oxides, Sulfur Oxides, CO_2 particles, Dioxins and odor elimination and then passing the exhaust gas through the cellulose nanofiber filter. It wills filtration of the nano size particle, after that purified air can flow to the outside of the cellulose nanofiber filter.

In the final stage, the purified gas can some amount of heat energy (Qc). That wasted heat energy is used for the burning process. The waste heat was recirculating to intake. So that, the fire point of the fuel will quickly reach. So, we get more efficiency:

$$C_6H_{12}O_6+6\ O_2 = 6\ CO_2+6\ H_2O \tag{1}$$

Wood (sugar) oxygen carbon dioxide water:

$$2CO+O_2 2CO_2 \tag{2}$$

$$RCH_2OH+CO_2\ R2COOH+1/2O_2 \tag{3}$$

$$RCH_2OH+NO_2RCOOH+H_2O+1/2N_2 \tag{4}$$

IAP meter: The goal of the IAP meter is to monitor indoor CO and PM concentrations in the quantification of reductions in hazardous emissions from cooking stoves.

Features

Carbon monoxide and PM 2.5 concentration tests: Includes the exposure control backpack and snorkeling hose. Three frequency modes of samples:

- Quick mode: battery life of 9 seconds for 3 days
- Med mode: battery life 51 seconds, CO over filtration 2 weeks
- Slow mode: battery life 9.7 min: 1 month CO over noise filtration sampling

Live monitor and contact port serial output: Live view graph device compliant RS-232/USB adapter.

LED indication light: The 5 sec blind shows IAP meters are on solid light showing configuration mode.

IAP meter working (Fig. 16): The kit comprises two sensors, a fan, a joystick, a rechargeable battery and an SD card. The control circuit activates the sensors and starts to report the signal they send. The fan and sensors are temporarily turned on to take a sample and then shut off again to conserve battery power. The fan pulls the air sample in the box to allow for precise analysis of contaminants. When checking, the box remains locked. The meter is shut off and a data file is closed after the test which enables a computer to interpret data.

The carbon capture is an electrochemical cell. The conductivity of two electrodes in proportion to the CO concentration varies when exposed to CO.

The PM sensor is used to diffuse optical light. Both a laser and a light receiver are within the sensor. The light from the laser rebounded in the receiver as smoke reached the sensing chamber. More light to the recipient reveals more moisture in the space. This light level was matched to the regular laboratory nephelometer to match the reflected light to the smoke particles concentration.

The data is interpreted by Microsoft Excel or related applications. The software analyses transform and generate documented data into physical quantities in the graphical and tabular form. Average thresholds as well as a maximum 15 min average are automatically presented in a format conveniently replicated to a master table to be compared to other measures.

Placement of the meter: For comparable measurements, clear meter positioning is important. As seen in Fig. 17, typically, the meter is roughly 1.3 m apart from the stove and 1.3 m up from the ground as it replicates a typical breathing area for the chef. Some people suggest 1.4 or 1.5 m. This is compounded by the construction and ventilation of the building. When you do something in a

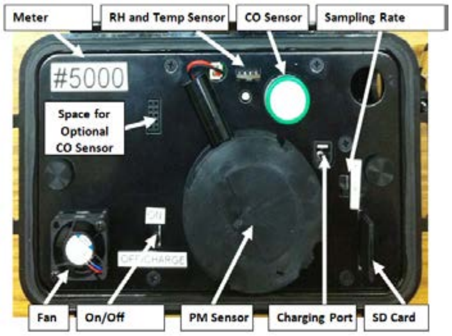


Fig. 16: IAP meter

Fig. 17: Placement of IAP meter

house before and after practicing, you must put the meter in that house at the same location. The University of California-Berkeley has done more extensive analysis of the suggested meter positioning.

Setting up the system

Additional requirements

Card reader: An IAP meter reader for the SD card. This is important to move the data to a computer. Any machines also have this motor.

Live output cables: The cables supplied with the IAP meter 5000 series are inserted into a device and linked to both the meter and the calibration screen for live data viewing. They are a DIN serial cable that is directly attached to the meter and is linked to the device via. a serial USB cable (Fig. 18).

Software: Data can be processed via. Microsoft Excel or other similar spreadsheet software on Windows, Mac and Linux operating systems. Two versions of the Table Program are available, one with visual basic macros and the other without visual basic macros. Only PCs that are Microsoft Excel 2003 and older are supported by Visual Basics Macros data processing tools. The IAP Meter program contains the latest program for the data collection and the use of the meter in live operation mode.

SD card folder: The data analysis tools for series 5000IAP meters can also be downloaded on the www.aprovecho.org (Fig. 19).

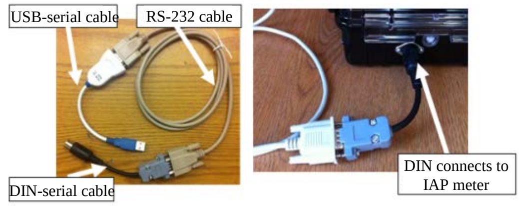


Fig. 18: Cables used in IAP meter

Fig. 19: Power chord

Charger control cable: A power cord with a US-style connector is included with the charger. If the local outlets do not suit, the cable given will use a basic adapter.

Software folder: The IAP Meter SD card includes an IAP meter archive. It contains this manual, data processing map, Terre term (the program used to connect the meter directly to a computer) and Live map (to calculate output). It contains the instruction manual. Copy or pass this folder to your hard drive before using the IAP meter. Moreover, create a folder called C:\IAP-Output\ on your C:\drive. Here is where all. csv files will be copied from your meter.

Meter setup: The IAP meter will arrive with the battery detached, depending on the shipping process. The battery needs to be mounted if that is the case. You need to remove the meter panel to install the battery.

You can see where the battery and the accompanying wire link after removing the frame. Only plug this in and put the battery firmly into the bottom of the shell. Make sure the wire jack is wired securely. Substitute the row following video instructions.

Switch on the meter to make sure it works. The Red LED will be lighted around 5-10 sec when the meter is first activated. Then every 5 sec it will flash around which means that the meter works. You will watch the IAP meter sample based on the sample speed chosen. The top of the PM sensing chamber can be removed and any sample can be seen on a rotary laser. Any sample can also be seen as the fan spins. The start of the meter will take up to 1 min. A third way to validate the meter is to connect it via a serial port to a device and to display the data. Section 9 of this text contains guidance on how to do this.

Running a test: The test requires the collection of the sample rate, the setting of the meter, closure of the cap, sampling and then recharge and processing of the data for at least 10 min.

It is good to allow the meter, particularly when it's traveling from a hot car to a cool space, to acclimatize at local temperatures before approaching the example spot. Enable the meter to sit with a lid open and turn off the meter from direct sun for a few minutes. This helps to create the correct temperature and cooling baseline for the CO sensor signal.

Selecting the sample rate: Specify a transition to sample rate fast, medium or slow. If when the sample rate is triggered, the sample rate will not change until the system is turned off again when the IAP meter is triggered.

Live data output: The RS-232 (9 pins) device connector cable and the RS-232/USB adapter is supported for the IAP meter. You will attach the IAP meter to the serial port of your device to display the raw data information, to monitor the information and to adjust calibration constants.

You would have to install suitable drivers to allow the adapter to operate properly while using a USB connexion. Copy the related driver folder to your C:\drive for the download. You can find this folder on your CD program. It is called 'FTDI Chip USB Serial Adapter' ensure that your device copies the matching 32-bit or 64-bit archive. Attach the RS-232 to the USB connector to the device USB port. A UC232R system driver program needs to be mounted in a browser. If not, go to the computer manager in the system folder in the control panels or press the device manager button on the screen. Double click on a small yellow triangle on the Universal Serial Bus.

With an exclamation mark Click "Drivers" on the top of the window which opens. The "Edit Drivers" button is then relocated. This opens the install window of the driver. During the driver update, choose the option to use your drivers and choose the folder that you have previously installed on the C:\drive. Twice until the system is recognized by your user, you may have to go through the installation process.

Serial port output:

- The IAP Meter will give an output like this when it is turned on:
- #testing: humid OKCO OKCO$_2$, ..., CO$_2$err #IAP-4000j_cell_8
- #type Cal (in 5 seconds) #?, ..., starting logging #CO initialized
- #initializing SD card, ..., done #clock initialized
- #year: 2019 month: 4 day 1: hour: 17 min: 26 sec: 55
- #start time: 56159 #make new file name
- #new name: 2019_04_01_172655.csv #files open
- #waits for timer #fast sampling
- #init i2c libs…. done, measure and log
- # CalVal: XX, PB, TE, CO, PM, TO, C2#,614, 0.0408, 0.0326, 1.65,1
- ##, ##
- Seconds, batt, adc_temp, CO, PM, humidity, top_temp 9, 81, 710, 111, 551, 47, 19

Line 1: When you see line 1, you have 5 seconds to type the word "cal" to enter setup mode and change the calibration constants.

- Line 12: sample speed
- Line 15: calibration constants
- Line 18: Start of the data output
- Column 1: time (seconds)
- Column 2: battery life (percent charged) Column 3: Temperature (log units) Column 4: CO (log units)
- Column 5: PM (log units)
- Column 6: RH (relative humidity) Column 7: Temperature (°C)

Using the data: The data is supplied in a column format such that a description table for comparison with other samples can be copied quickly. Please ensure that when copying data into another table, you select Specific paste values (Fig. 20). An explanation of how data can be merged to include the average and variance of the test series is given below.

Energy use:

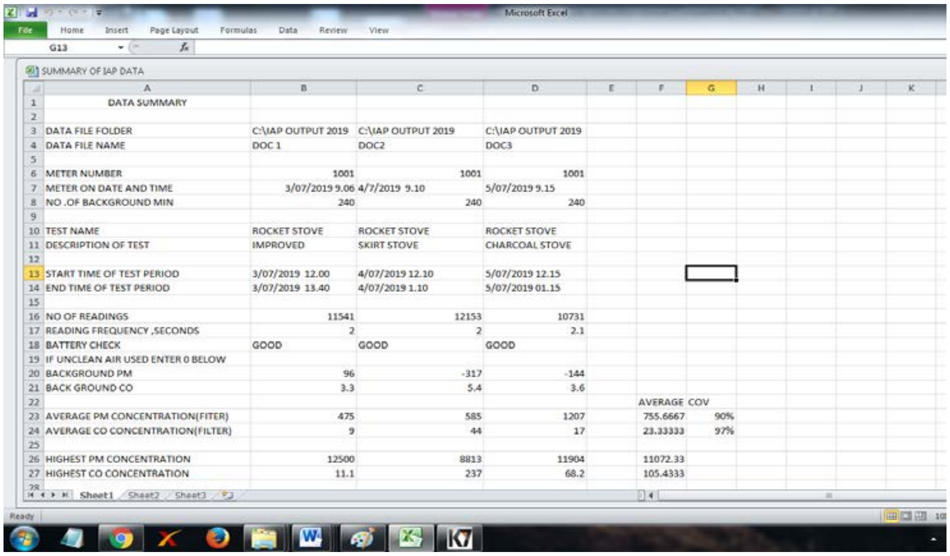
$$E = C * V * \Delta t/PR$$

Where:

E = Energy (kWh)
C = Specific heat of water-0.94 kcal/kg°C
V = Volume of water to heat (liter)

$$\Delta T = T_2 - T_1$$

T1 = Temperature of hot water (°C)
T2 = Temperature of cold water (°C)
PR = Performance ratio (it includes loss of heat), default value = 0.9
E = 0.94*1.839*(95-25.5)/0.9
E = 133.9 KW for a day
E = 2.23 KWH
E = 10.5 MJ



SUMMARY OF IAP DATA

	A	B	C	D	E	F	G
1	DATA SUMMARY						
2							
3	DATA FILE FOLDER	C:\IAP OUTPUT 2019	C:\IAP OUTPUT 2019	C:\IAP OUTPUT 2019			
4	DATA FILE NAME	DOC 1	DOC2	DOC3			
5							
6	METER NUMBER	1001	1001	1001			
7	METER ON DATE AND TIME	3/07/2019 9.06	4/7/2019 9.10	5/07/2019 9.15			
8	NO .OF BACKGROUND MIN	240	240	240			
9							
10	TEST NAME	ROCKET STOVE	ROCKET STOVE	ROCKET STOVE			
11	DESCRIPTION OF TEST	IMPROVED	SKIRT STOVE	CHARCOAL STOVE			
12							
13	START TIME OF TEST PERIOD	3/07/2019 12.00	4/07/2019 12.10	5/07/2019 12.15			
14	END TIME OF TEST PERIOD	3/07/2019 13.40	4/07/2019 1.10	5/07/2019 01.15			
15							
16	NO OF READINGS	11541	12153	10731			
17	READING FREQUENCY ,SECONDS	2	2	2.1			
18	BATTERY CHECK	GOOD	GOOD	GOOD			
19	IF UNCLEAN AIR USED ENTER 0 BELOW						
20	BACKGROUND PM	96	-317	-144			
21	BACK GROUND CO	3.3	5.4	3.6			
22						AVERAGE	COV
23	AVERAGE PM CONCENTRATION(FITER)	475	585	1207		755.6667	90%
24	AVERAGE CO CONCENTRATION(FILTER)	9	44	17		23.33333	97%
25							
26	HIGHEST PM CONCENTRATION	12500	8813	11904		11072.33	
27	HIGHEST CO CONCENTRATION	11.1	237	68.2		105.4333	

Fig. 20: User data collected from IAP meter

RESULTS AND DISCUSSION

Average removal efficiencies over a burning cycle. The two filters displayed high efficiencies in the elimination of both fine and organic carbon particles and both fillers had the best efficiency. The filter Knapsack revealed that ultrafine particles are also excluded. In simulated carbon with cellulose nanofibre filter, no net elimination of ultrafine particles over the whole burning period (40 min.) have been observed but gases including CO_2), nitrogen dioxide (NO_2) and carbon monoxide and voluntary organic compounds have been full. The gases have been eliminated. VOCs are compounds used in many different materials. VOCs are organic substances.

When wood is burnt, the combustion results create water, chemical vapors, gases and particulates in the form of heat and pollution. Carbon (CO), carbon (CO_2), sulphur (SOx) oxides and nitrogen oxides (NOx) are among the major pollutants. The emissions are measurables for other controlled products and substances including mercury and hydrochloric acid but are well below agreed limit standards. The combustion temperature determines the composition and volume of pollutants. Higher temperatures facilitate full combustion and contribute to cleaner emissions. Emissions will also contain volatile organic compounds, relatively high CO levels (a result of incomplete combustion) and other particulate problems at lower temperatures. Burning bodies with NOx and SOx emissions are significantly smaller than the biomass and petroleum fossil products pollution and equal to natural gas emissions. Particulate emissions in the wood are close to those in coal and petroleum combustion and slightly greater than amounts of natural gas emissions. The smoke stacking systems such as scrubbers, bag filters and electrostatic precipitators can be used to regulate particulate emissions to appropriate standards. However, this device is only economically viable for large commercial combustion systems. Smaller appliances may have specific emissions, particularly residential units. There is a growing amount of limitation on breathable (PM2,5 or <2.5 microns particulate matter) in cities and districts of pollution quality. Wood combustion unregulated emissions in PM2.5 are large. The amount of CO_2 produced during combustion is essentially the number of carbon trees required to produce the same amount of wood as the amount of wood used in combustion is known to be ‘carbon neutral’. The burning of wood thus does not lead to the net rise in carbon dioxide (greenhouse gas) levels in the atmosphere and fossil fuel emissions. The essential elements present in the pollution are seen in Fig. 21 according to research[30, 31].

Suggested fuel (energy) use benchmark: The improved cookstove should use <15 MJ of energy to complete the WBT.

Filtration of exhaust gas: Exhaust gas is flowing through the exhaust pipe to passing our filters. The following elements are filtered by the following filters in Table 3 and Fig. 22.

The knapsack filters deal with the particles such as PM10 and PM2.5 whereas it efficiently removes about 98 and 90% of PM10 and PM2.5 of respectively. Because in our design simulated carbon with cellulose nanofiber filters are very sensitive to particles which will reduce the lifetime of the simulated carbon with cellulose nanofiber filter. So that, the first passing exhaust gas to the

Table 3: Average removal efficiencies over a burning cycle

Parameters	PM_{10}	$PM_{2.5}$	CO	NOx	VOC	Sox
Knapsack filter	98%	90%	0	0	0	0
Simulated carbon with cellulose nanofiber filter	0.2%	10%	97%	95%	90%	89%

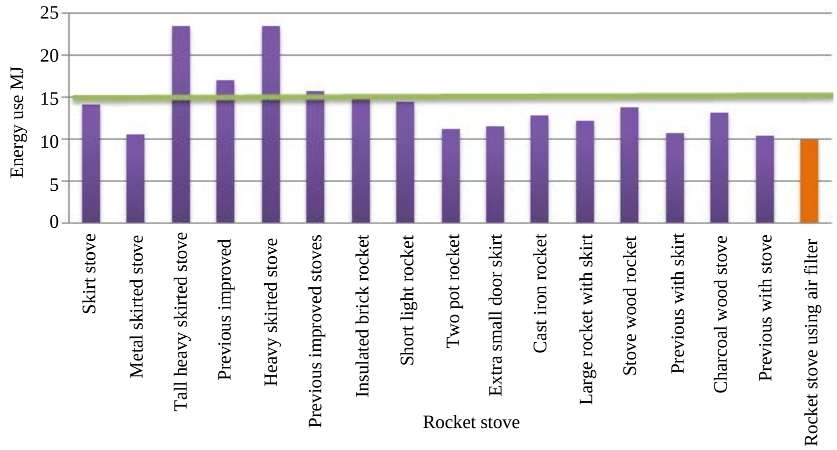


Fig. 21: Energy use for stoves to complete the WBT (Megajoules)

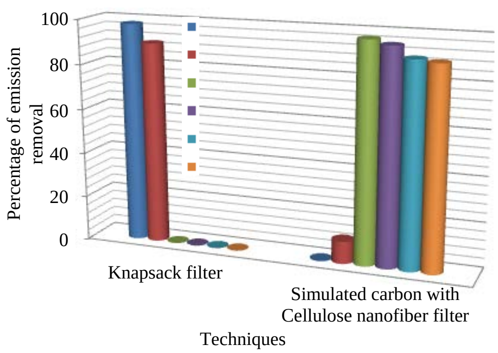


Fig. 22: Removal quality of filters

knapsack filter shown in Fig. 23. It is passed through the simulated carbon with a cellulose nanofiber filter. This filter will remove the toxic contents of about 0.2% of PM10, 10% PM2.5, 97% of CO, 95% of NOx, 90% of VOC and 89% of SOx.

Suggested carbon-monoxide emission benchmark: The improved cookstove should emit <20 g of carbon monoxide to complete the WBT (Fig. 24).

Suggested particulate matter emission benchmark: The improved cookstove should emit<1500 mg of particulate matter to complete the WBT (Fig. 25).

In our proposed method the thermal efficiency is improved due to the waste heat recovery system. When comparing the performance of rocket stoves without a heat recovery system with our proposed framework, the proposed work exhibits about 70% thermal efficiency, whereas the prior methodologies achieve only 45%. Thus, the efficiency is improved by 30% which is shown in Fig. 11. Moreover, the average fuel consumption of our proposed methodology is compared with the prior methodologies such as traditional rocket stove and catalytic rocket stove which is shown in Table 4 and Fig. 26.

Here, Fig. 12 shows, the fuel consumption rate is very low for our proposed methodology 400 (g L^{-1}), whereas the traditional method consumes 600 (g L^{-1}) and the catalytic methodology consumes 530 (g L^{-1}). The result shows fuel efficiency rather than the existing (Table 5).

In the case of PM reduction in Table 3, our proposed methodology reduces the average emission to 1750 (μg m^{-3}) while on dealing with the prior methodologies traditional as well as catalytic the average reduction is about 5500 and 3800 (μg m^{-3}), respectively. Thus, the system exhibits better results with the reduction of PM emission and is demonstrated in Fig. 27.

Similarly, by Table 6, the concentration of CO is measured using an indoor IAP monitor which reveals that the proposed methodology releases less concentration of CO (8 ppm). But in terms of existing methodologies, the concentration of CO is very high, i.e., 35 and 15 ppm, respectively and is shown in Fig. 28.

Thus, the overall experimental and the comparison results reveal that our proposed methodology achieves better-optimized efficiency results in terms of fuel efficiency, thermal efficiencies, reduction in the emission and concentration of PM as well as CO than the prior methodologies such as the traditional rocket stove and the catalytic rocket stove.

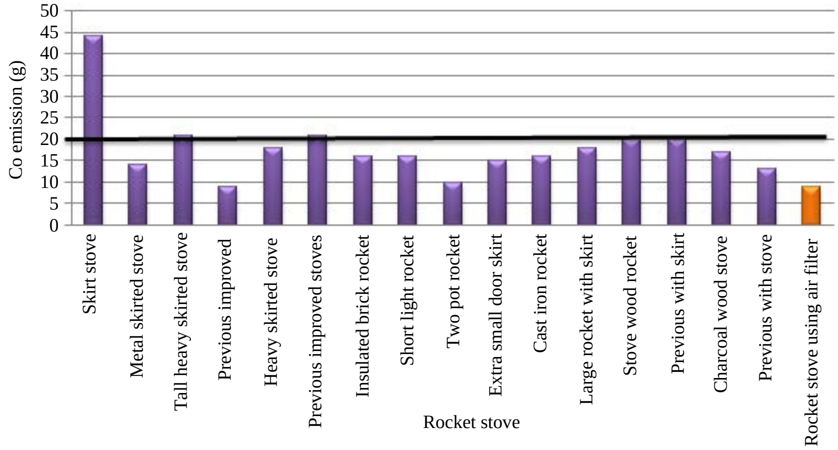


Fig. 23: Carbon-monoxide emissions to complete WBT (g)

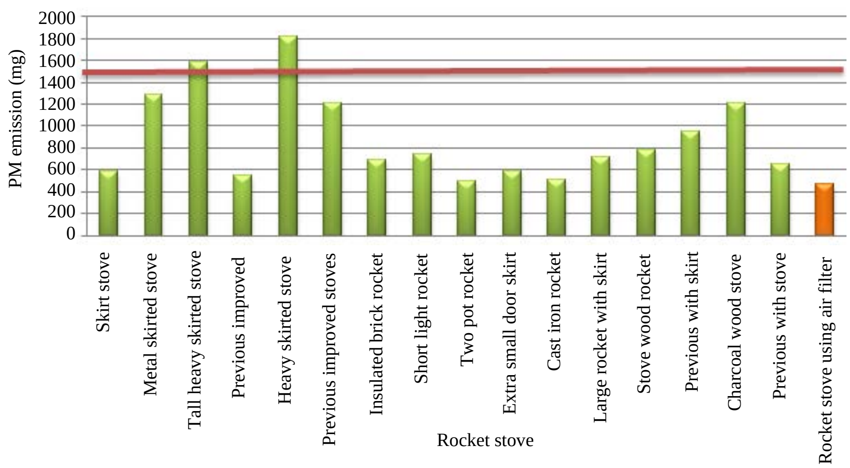


Fig. 24: Particulate matter emissions to complete WBT (mg)

Stoves without combustion chamber

	1. Three Stone Fire	2.GhanaWood	3.Mud/Sawdust	4.BaldwinVITA 6.Modi?edVITA	7. Modi?ed	VITAw/Insulation 5.	Cast 8. SkirtStove	Iron Stove fromIndia
BenchmarksMet?	NO	NO	NO	NO	NO	NO	YES	NO
EnergyUse(MJ)	21.8	15.2	13.1	11.6	18.6	20.4	13.1	14.2
PMEmission(mg)		1674	2352	2150	3509	1424	882	585
	4287		49	43	50	35	16	44
COEmission(g)	65	50	754	668	1017	1062	681	814
FuelUse(g)	1253	875	16.0	14.0	36.2	16.5	19.9	40.5
Time toBoil(min)	38.1	21.8						

Stoves with combustion chambers

Stoves with rocket combustion chamber

	9. Metal Skirted Rocket Rocket 10.Tall	11. Heavy Skirted	Previous Improved	12. Heavy Skirted Rocket	13. Previous Improved	14. Short Rocket Rocket	Insulated 15. Brick Light	16. Two-Pot Rocket	17. Extra Small Door w/ Skirt	18. Cast Iron Rocket	19. Large Baldosa Rocket skirte	20. Stove Tec w/Wood Stove	21. Previous with Skirt	22. Stove Tec Wood or Charcoal Stove	23. Previous with Skirt	**24. ROCKET STOVE USING AIR FILTER(existing model)**
BenchmarksMet?	YES	YES	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	**YES**
EnergyUse(MJ)	10.6	23.5	17.1	23.5	15.7	14.9	14.5	11.2	11.5	12.8	12.2	13.8	10.8	13.2	10.4	**10**
PMEmission(mg)	557	1289	1576	1806	1213	689	738	376	587	515	724	783	954	1207	654	**475**
COEmission(g)	14	21	9	18	21	16	16	10	15	16	18	20	20	17	13	**9**
FuelUse(g)	699	1282	927	1222	817	771	796	641	625	698	742	830	651	757	608	**400**
Time toBoil(min)	40.0	22.3	58.0	21.8	21.6	34.9	30.5	43.8	12.2	29.4	30.0	37.7	24.6	30.8	23.3	**12**

	Gasi?ers			Forced air stoves					Charcoal stoves	Liquid/gas fuels			Gasi?ers		
	25. Charcoal-Making gasi?er	26. Exper-imental Gasi?er	27. Large Gasi?er	28. Grid-Powered Fan	29. Battery Powered Fan	30. Wood Stove	31. Bottom Air Gas	32. Fan Aprovecho Rocket with Fan	33. Mali Charcoal	34. Charcoal with Skirt	35. Charcoal JikoStove	36. StoveTec Wood/ Charcoal Rocket	37. Propane (LPG)	38. Ethanol	39. Kerosene
Benchmarks Met?	NO	YES	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO	YES	YES	YES
EnergyUse(MJ)	13.6	17.6	22.0	15.3	10.8	10.5	9.4	15.0	19.8	19.1	20.8	12.6	6.7	6.8	9.7
PMEmission(mg)	1001	70	225	89	293	48	27	151	260	251	71	44	5	4	10
COEmission(g)	8	27	43	4	6	9	7	6	113	102	71	41	1	5	8
FuelUse(g)	741	961	1234	792	614	609	460	722	655	613	657	439	140	317	223
Time toBoil(min)	26.4	27.3	17.9	13.2	13.9	19.5	23.7	33.7	38.6	18.9	28.3	30.0	23.0	31.6	42.5

Fig. 25: Value comparison between different rocket stoves

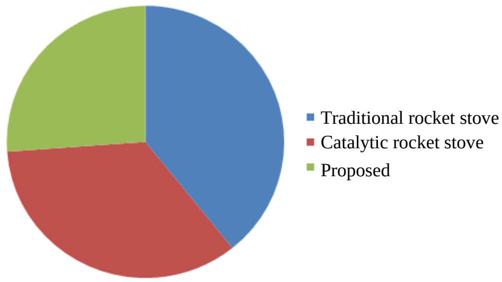


Fig. 26: Comparison of proposed with existing methodologies in terms of fuel consumption

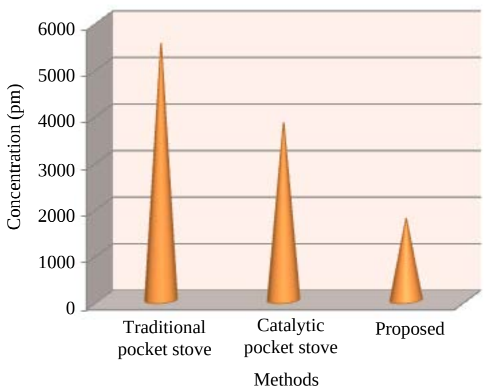


Fig. 27: Comparison of proposed with existing methodologies in terms of PM reduction

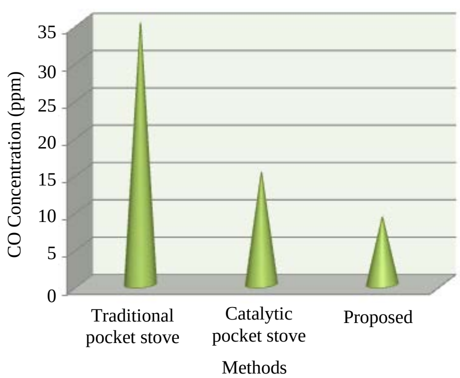


Fig. 28: Comparison of proposed with existing methodologies in terms of CO reduction

Table 4: Comparison of proposed with existing methodologies in terms of fuel consumption

Methods	Average fuel consumption (g/L)
Traditional rocket stove	600
Catalytic rocket stove	530
Proposed	400

Table 5: Comparison of proposed with existing methodologies in terms of PM concentration

Methods	Average PM concentration (μg m^{-3})
Traditional rocket stove	5500
Catalytic rocket stove	3800
Proposed	1750

Table 6: Comparison of proposed with existing methodologies in terms of CO reduction

Methods	CO concentration (ppm)
Traditional rocket stove	35
Catalytic rocket stove	15
Proposed	9

CONCLUSION

The rocket stove is the mostly used stove in the villages but exhaust gases are very dangerous to humans and animals. So, e proposed a methodology that has to discuss in this paper. We used the knapsack filter and simulated carbon with cellulose nanofiber filters. In our system, the knapsack filters are removed only the particles present in the exhaust and the simulated carbon with cellulose nanofiber filters are removed the chemical elements present in the exhaust gas. Both filters are highly efficient removal rate. In our research is used to reduce air pollution and also improve the efficiency of the rocket stove.

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