CHAPTER 7: STOVE RECOMMENDATIONS
7.1. Introduction:

The laboratory testing on the 10 wick stoves, 7 pressure stoves and 4 camping stoves, as well as user testing on 6 stoves revealed a number of problematic and even hazardous stove design features. In this chapter, I provide a set of recommendations on design factors for paraffin stoves to assist future designers in developing low-cost stoves that are more efficient, have a better power range, are ergonomically better to use, will have a reasonably long working life and will meet minimum safety standards.

7.2. Wick Stove Recommendations

The range of wick stoves available to low income households have a number of features that are problematic to the user. These problems include:

- The stoves are reasonably unstable and can be knocked over easily
- The stoves do not last long as the construction materials deteriorate quickly
- The stoves are generally not very efficient, the power ranges (minimum and maximum) are not very broad
- The mechanisms to control the stoves are ergonomically unpleasant to work with
- The fuel in the fuel vessels reaches temperatures beyond the flashpoint of paraffin during use
- When filling the stove, fuel is often spilt and this pools in manufacture reservoirs on the top of the fuel vessel
- Users dismantle key stove performance areas (diffusers) in order to light the stoves
- Users are expected to blow the stove out instead of use a controlled shut down system.

However, amongst the poorest population in South Africa these stoves are popular. The reasons for this include the cost of the stoves and the simplicity of working and maintaining these stoves.
A number of recommended design factors to address the aforementioned problems are outlined below.

7.2.1. Body construction and aesthetics:

The body construction is not only the physical construction principle of the stove but also the aesthetic selling feature of the stove to its market. For the safe use of a paraffin stove the aesthetic elements are of least concern. As a designer these elements do add some value to the end user in terms of acceptance of the product and the perception of the user of the product. Market forces are likely to influence the outer body aesthetics. In order to further understand what the typical consumer in this market would rate as visually appealing and psychologically acceptable, a series of user centred design process exercises needs to be conducted. However, the laboratory testing did give an indication that some of the aesthetics of the products should be guided by what fundamentally makes for a better functioning stove.

During the testing it was found that the open body constructions on the Swastik stoves were most effective in reducing heat transfer to the fuel vessel. Furthermore, this type of structure allowed the user to access areas of the stove for filling and cleaning. The chrome finishes on the Swastik stoves conveyed a quality that raised this stove’s status above that of the rest of the wick stove range, even though the actual underlying material was the same 0.3mm mild steel used elsewhere. The thick vitreous coating on the Everbite stove also created a similar effect; this was enhanced by the cast iron potholder. Although these additions appear to be more expensive, the manufacturing processes and materials used make them economically viable to include in these types of stoves. Adding above average quality finishes to wick stoves in
future could increase the stoves working life quite substantially without adding enormous costs to the selling price.

My recommendations on body construction and aesthetics are therefore as follows:

- Any design work in this area requires direct interaction with users.
- Suggestions for potential forms include an open box form with pillar legs or the open tripod legged barrel form similar to the Swastik. Any forms considered, however, would require a larger footprint than the standard Ø225mm pot\(^1\) as described in stove testing.
- The surface finish and selection of materials is crucial, not only for the marketing value of the stove, but also for the durability of the stove. However, as cost is an enormous factor for low income households, the design needs a careful selection of materials for structural strength in the right areas.
- The inclusion of materials such as cast iron (as in the Everbite potholder) add perceived value to the stove without impacting on cost, such considerations in all areas of the stove should happen.
- The body construction should allow for easy maintenance, filling of the fuel vessel and cleaning by the user.

7.2.2. Wicks and wick mechanisms:

Of the stoves tested in the laboratory the mechanisms that appear to produce the best results are the multi-wick or ‘range wick burner’ systems. Of these, the two Swastik (King and Medium) stoves performed the best overall with their combination of a large diameter wick

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\(^1\) Information obtained on 7\(^{th}\) October 2004 from Hendler and Hart: the Ø225 mm diameter aluminium pot that was used for all the testing (code number J7 225), sales = 5 500 per week. This pot is the most popular pot in the Hendler and Hart range. The pot is aimed specifically at the middle to lower income group.
arrangement (any dimension from 85mm and up) and a tall stilt carrying structure. The number of wicks in the multi-wick setup should be 6 or more as this gives a large even surface area for the heat spread on the base of the pot for cooking.

For the improvement of wick stoves, Bussmann, Visser and Sangen (1987), indicate that the ‘range wick burner’ mechanism should be situated further away from the fuel vessel to reduce the fuel temperature in the tank. Lloyd (2002) recommends “making the connection between the burner and fuel tank of a low-thermal-conductivity material” (Lloyd, 2002: 5). The alternative to this is to include a radiation shield to protect the tank from the radiant heat from the burners (Bussmann, Visser and Sangen, 1987; Lloyd, 2002).

The diffuser arrangement of having the closed top inner diffuser with a single outer diffuser and then a closed shield shroud surrounding this is well trialled and works. The closed shield shroud also protects the outer body from heating up, causing more transfer heat to the fuel vessel. The materials for these components need to withstand the heat that is generated in this area and any protective coating (rust proofing) must be resistant to these temperatures for the components to last.

The “maximum and minimum power are determined by the size of free wick end and temperature” (Bussmann, Visser and Sangen, 1987: 2). To raise the level of power in the wick stove, Bussmann, Visser and Sangen (1987) suggest the closing of the gap between the outer diffuser and the shield; this will have the effect of raising the temperature in the diffusers and through this the air temperature around the wicks making for higher power output. Other solutions include raising the height of the diffusers without any change to the air hole density.
on these (Bussmann, Visser and Sangen, 1987). Wick life time can be extended by limiting
the amount of oxygen in the vicinity of the wicks (Bussmann, Visser and Sangen, 1987).

The diffusers have several key effects on the stove. They build up heat which assists in
heating up and vaporising the paraffin around the wicks making the combustion in this area
more effective (Floor and van der Plas, 1991). This build up of temperature also heats the air
coming in from outside of the stove; warming this air is better for combustion (Floor and van
stove is required for the combustion of the kerosene vapour. Therefore air has to enter the
combustion zone via the shield and outer flame holder, and the inner flame holder. If too
much air is drawn into the stove via the inner flame holder, relatively more air will escape via
the hole at the top of this flame holder. This will result in a wider flame plume above the
stove and consequently the efficiency will be lower” (Floor and van der Plas, 1991: 28)
Further to this, they add that the amount of air coming through the diffusers will affect the
temperature of the gases leaving the stove (Floor and van der Plas, 1991). Thus the
perforations in the stove diffusers are specifically calculated to control the amount of air
entering the burn area (Floor and van der Plas, 1991). Suggestions for improvement in this
area are to introduce an air flow restrictor in the centre and at the base of the wick burner
mechanisms, thus allowing for variety of control depending on the temperature of the ambient
air (Floor and van der Plas, 1991). An additional benefit, according to Floor and van der Plas
(1991), would be that this air restrictor could act as a shield to keep radiant heat from the
burners from heating up the fuel vessel.
A summary of recommendations for the wick mechanisms:

- The stoves should be designed with a multi-wick system or ‘range wick burner’ system for better spread of heat.
- The stoves should have good maximum (2.5kW) power and good minimum power (0.75kW).
- The wick mechanism needs to include devices that prevent heat transfer to the fuel vessel and through this the paraffin inside.
- The gap between the outer diffuser and outer shield should be experimented with against the findings of Bussmann, Visser and Sangen (1987).
- Experiments should determine whether closing the gap between the inner and outer diffusers could increase power and what effect this will have on efficiency. Furthermore, according to the findings of Bussmann, Visser and Sangen (1987), the height of the diffusers needs to be experimented with. This experiment must consider the conflicting requirement of reducing the overall height of all aspects of the wick stove in order to create greater stability.
- Air flow between the outer diffuser and outer shell shield needs to be experimented on to determine the optimum distance between these two. According to Floor and van der Plas (1991) restricting this area can allow for better stove efficiency.
- In conjunction with the above assertion, the system of controlling air coming through the inside of the inner diffuser can also lead to better stove efficiency and will need to be experimented with (Floor and van der Plas, 1991).
- Bussmann, Visser and Sangen (1987) indicate that there is a relationship between stove efficiency and the distance between the burner and the pot base. This aspect would need some experimentation to determine the optimum position.
• The inclusion of a self extinguishing device in accordance with the requirements of SANS 1906 (2005): “The appliance shall extinguish itself within 30s, if tilted at 45° or greater when alight” (SANS1906, 2005: 6).

• Bussmann, Visser and Sangen (1987) propose that all air leaks should be avoided around the flame holders i.e. where the diffuser fits around the wick exposed ends. Furthermore, the “first 20mm of the flame holders should not be perforated, thus leaving the wicks enough space to freely evaporate the kerosene. This also implies that the maximum wick level should not exceed 20mm” (Bussmann, Visser and Sangen, 1987: 36).

7.2.3. Control of the flame:

Stoves that have plastic controllers seem to exude better quality and are generally ergonomically better as these controllers stay cooler to touch during use. The plastic controllers need to be placed out of the area where heat transfer could raise their temperature to unsafe levels and melt or burn them. The controller should include some graphic instruction for the user to understand minimum and maximum settings. Investigations into the most appropriate form of graphic or pictogram usage should be considered.

My recommendations are as follows:

• Bussmann, Visser and Sangen (1987) suggest that on multi wick or ‘range wick burners’ the travel of the wick should be maximum of +25mm above the wick holder and a minimum of -15mm below the wick holder.

• From the users testing it was noted that the test group did not use the control mechanism provided to adjust stove settings. Perhaps a simpler, easier to comprehend control system needs to be designed to suit the cooking needs: simmer, boil/fry and a
medium setting. Or alternatively instructions should be given that promote better control practice by the user.

7.2.4. Fuel vessel:

The fuel vessel should be of a size that has enough fuel to cook a standard meal for a week. From the user testing, it was found that users consume between 150ml and 200ml of fuel per meal. Suggestions are for a stove to be equipped with a 1.5 to 2.0 litre fuel vessel; this would prevent the user from refilling the stove too often. Additional consideration should be given to making this vessel wider and flatter, and through this reducing the overall stove height and creating a more stable base.

There should be some consideration for being able to see how much fuel is in the vessel when filling the stove and when the stove is in use. The fuel gauges supplied on two of the stoves tested appeared not to work (Everbite and Swastik King). It would be useful for the user to know how much fuel is available in the fuel vessel, so the inclusion of a simple working gauge may be required.

The area where the most fuel appears to leak is at the connection between the fuel tank and wick burner mechanism. In the Panda, Giant, Man, Skeni and Paraburn stoves, this area relied on a rivet manufactured bayonet fit or a friction fit. Both systems are loose and of poor fit. In the 3 Swastik stoves, the manufacturers use a combination of butterfly nuts with flat ring seal around the area assembling the burner mechanism to the fuel vessel. This has a combined effect of ensuring no leakages occur in this area and the seal creates a layer between the wick burner and fuel vessel and this reduces heat transfer to the fuel vessel. The Swastik system is far superior to the other stoves tested and effectively seals the fuel vessel.
As the fuel vessel is sealed here these stoves require that there be a hole in the filler cap to avoid a vacuum starving the wicks of fuel. With the addition of a sprung loaded mechanism this hole could be easily blocked if the stove was knocked over thus preventing any potential fuel leaking.

A summary of the fuel vessel recommendations:

- Reduce the overall height of the fuel vessel, but not the volume. The volume should remain between 1.5 litres and 2.0 litres.
- Make the footprint of this fuel vessel at least wider than the standard Ø225mm pot size.
- Increase the filling orifice size and devise a mechanism to prevent filling whilst the stove is in operation (according to the SANS 1906, 2005 stipulation).
- The alternative arrangement is to separate the fuel vessel from the stove by “providing a small well for the wick, which was fed with paraffin via a flow-limiting orifice, so limiting the rate of release of fuel if the appliance was knocked over” (Lloyd, 2002: 5). The additional components required for this configuration could add to the overall cost of the stove and may prove to be too expensive.

7.2.5. Filling the stove:

In order to fill the stove several factors should be considered:

- The stove should be designed with easy access to the filling area and also allow for the user to clean this area easily if any fuel is spilt.
- The filler cap should be placed in a position that allows for easy access. The access to this filling area should allow for bottle filling and funnel filling.
• If the filler area is on top of the fuel vessel, then the fuel vessel should not have any area that may pool any spilt fuel.

• A larger size filling orifice should be included and a suggestion for this is a minimum of Ø30mm.

• The filler cap should be designed with enough grips for a user to be able to remove and replace securely and easily.

• The principle of the attachment mechanism of the fuel cap to the fuel vessel (bayonet, friction fit, clipping, screwing or other) should consider functionality over cost effectiveness when design decisions are made.

7.2.6. Lighting the stove:

In order to provide for the effective lighting of a stove, several factors should be considered:

• Users should not be required to disassemble the diffusers to light the stove.

• A light assist should be supplied if the users do not remove the diffusers when lighting the stove.

• Simple instructions should be supplied that demonstrate how to safely use the light assist.

• Users should be able to purchase replacement light assists or the information supplied should show a simple procedure for the user to manufacture their own light assist with consideration given to readily available materials.

• The length of the light assist should be such that the user will not burn their fingers when lighting the stove, especially in the winter months when the fuel takes longer to catch fire.
• The light assist should be able to absorb enough fuel to allow more time to light the wicks, especially if the stove is a multi wick or ‘range wick burner’ type.

7.2.7. Stability:
Issues related to the stability of the stove are focused mainly in two areas of concern. The first is the surface that the stove will be required to perform on. The second is the stoves overall height.

Where the stove will be used is difficult to determine. The stove may be used on the ground or on a surface that is uneven instead of on a clean flat working surface. The stove designer needs to accommodate for the variety of scenarios. The stove base or footprint needs to consider how much space an average low income household would have to cook on if they were to cook on a work surface.

The configuration of current wick stoves makes for a tall structure that is inherently unstable. This structure includes the fuel vessel at the base, the wick mechanism and sleeves carrying the wick in the middle portion with its diffuser setup and the potholder area on top. Once a pot is placed onto these stoves the centre of gravity is raised to an unstable level.

With these constraints in mind the following recommendations could assist in making the stove more stable:
• The surface that the stove will be used on cannot be determined and so all effort should be made to design a system that will be stable on uneven surfaces. Using a tripod leg arrangement will automatically make the stove stable; however the span
between tripod style legs allows the stove to topple in that direction even if the legs are space widely apart. Therefore a minimum of four legs is recommended.

- The stove should sit on feet rather than on the metal stove body rim (as in the Panda, Giant and Paraburn stoves). These feet should be spread as far as possible with a recommended diameter of at least Ø230mm on round stoves or for a square configuration at least 230mm X 230mm. Any size larger than this would be more acceptable.

- From the user testing, users tend to misalign the pot on the stove which can cause stability issues. The potholder area should be slightly larger than the standard Ø225mm pot.

- All attempts should be made to lower the centre of gravity as much as possible. This could be achieved by making the tank remote from the wick mechanism (i.e. a separate fuel tank with fuel line) or increasing the footprint size of the tank and reducing its depth. Other methods could look at reducing the height of the wick mechanism and the diffuser mechanism. This would require experimentation to see how this reduction would affect efficiency levels and flame temperature.

### 7.2.8. Potholder and pot standoffs:

The most effective design found during testing for a potholder was the single pressed potholder with integrated pot stand offs that was designed for the Swastik Medium stove. Although the gap created between the pot base and the pot holder was insufficient, the principle remained sound. A gap of at least 8mm between the pot base and the pot holder appears to allow for better flow of flame and heat in wick stoves.
Any of the potholders that had pot standoffs that were spot welded or even mechanically fastened to their tops had structural issues early in the stove use. Furthermore, the stoves where the pot stand offs were directly in the stoves flame had problems with rust in the areas where the powder coating had burnt off. All pot standoffs should be designed to remain out of the stoves flame. The number of pot standoffs didn’t appear to make a lot of difference to stability; however it is recommended that a minimum of four should be considered.

Some design thinking needs to take place around how to deflect overflowing liquids from the pot placed on the stove and this should be integrated into the design of the potholder. Stoves like the Panda and Giant have made some effort in relieving this problem by raising the inner rim of the potholder and allowing the pot overflow liquid to run down the outside of the pot and not into the wick burning area.

On double stoves the distance between the two burners needs to be far enough apart to allow two Ø225mm standard pots to be placed next to each other and at the same time centrally on each individual burner unit.

7.2.9. Extinguishing the flame:

The ultimate solution for extinguishing the stove is for the stove to be able to turn down to its minimum setting and automatically extinguish itself. The design of an effective extinguishing system should become a priority when designing a new wick stove. The Swastik stove is supplied with a snuffer which will deprive the flame of oxygen, thus putting out the flame. The obvious restrictions on mechanical systems adding too much cost to the final product should be borne in mind.
• Blowing the stove out is unacceptable as this can cause a conflagration of flame from the wick burner and may burn the user.

• Stoves must resolve the issue of turning off after use. A suggestion is for an assembled cover, that can be worked in conjunction with the stoves control mechanism, that starves the air to the wicks or snuffs the wicks out from the top.

7.2.10. Economics:

An issue which is difficult to circumvent is the final cost to user of the stove. The wick stove market is regarded as one of the lowest income markets in the country. Below this market would be people who use wood burning fires and coal burning fires without specially designed stoves. Therefore all aspects of running costs need to be carefully considered.

• For 2007, the stove cost for this market should range between R 30-00 and R 75-00. Any stoves that cost beyond this would fall within the pressure stove market or even LPG stove market.

• The efficiency level needs to be above 60% if the stove is not to be wasteful of fuel when cooking. Any figure below this and it would be more cost effective for the individual to be using other cooking means.

• The stove should be designed to last for longer. This would require a cost relationship between the qualities of materials required to manufacture the stove versus the final cost to the user.

7.3. Pressure Stove Recommendation

The typical complaints of pressure stoves are that they are difficult to light, the flame is difficult to control, the stoves are not stable, stove maintenance is complicated, there is reasonably high heat transfer to the fuel in the fuel vessel, the pump mechanisms do not
function well, the purchase price is substantially higher than wick burner stoves and the vapour jet nozzles are easily blocked by impurities in the fuel or by carbon build up. In addition to this, pressure paraffin stoves require more complicated manufacturing procedures to produce than the wick paraffin stoves. However, pressure paraffin stoves do have a number of factors that are favourable: the stoves are generally more efficient than wick stoves, the stoves can develop a good range of minimum and maximum power settings making them convenient for a variety of cooking needs and the materials the stoves are manufactured from make their shelf life much longer than wick paraffin stoves.

A number of recommended design factors are given here. These could assist a designer in developing a better pressure paraffin stove that will surpass safety requirements at a reasonable cost to the user.

7.3.1. Vapour jet nozzles:

“For a given pressure in the kerosene tank, the power primarily depends on the diameter of the nozzle. The theoretical relation between pressure, nozzle diameter and power output which depends largely on the square root of the differential pressure and a temperature component, was confirmed by measurements.” (Floor, van der Plas, 1991:38)

Further to this Bussmann, Visser and Sangen, (1987) had developed the idea that an empirical relationship exists between:

- “The nozzle diameter and the nozzle – burner head distance
- The nozzle diameter and to the burner head diameter” (Bussmann, Visser and Sangen, 1987:02)

They describe a system of assessing the “power output of a vapour jet burner is a function of the nozzle diameter, the vapour temperature and the pressure difference.” (Bussmann, Visser and Sangen, 1987:45)
They further developed a formula relating to this assertion:

“\[ P = C \cdot A \cdot \sqrt{dp \cdot (Ta/T)} \] (kW)

Where: 

\[ C = \text{a constant} \]

\[ A = \text{the cross sectional area of the nozzle (m}^2)\]

\[ dp = \text{the pressure difference [atmospheric versus vessel pressure] (Pa)} \]

\[ Ta = \text{the ambient temperature (K)} \]

\[ T = \text{the vapour temperature at the nozzle (K)} \]” (Bussmann, Visser and Sangen, 1987:46)

Bussmann, Visser and Sangen (1987) conducted a number of experiments on pressure stove systems. They experimented with jet nozzle diameters of Ø0.4mm, Ø0.6mm, Ø0.65mm and Ø0.8mm and a variety of distances between the nozzle and the burner head. Some of their findings were:

- Experiments with the nozzle diameter above Ø0.6mm gave less power as the flame blew away from the burner.

- The distance between the nozzle and the base of the pot effected efficiency – i.e. the further away the base of the pot from the burner the less efficient it becomes.

- The Ø0.6mm nozzle also developed a slightly higher power output according to the calculations above.

- There is a relationship to power and efficiency between the nozzle diameter and burner head distance and also to the nozzle diameter and burner head diameter.

- The nozzle diameter is restricted by the minimum power requirements.

- At lower pressures the nozzle diameter is required to be finer e.g. Ø0.4mm or Ø0.5mm
• Although the Ø0.6mm nozzle was deemed to be most efficient from the testing performed the ultimate choice according to their research was to have a nozzle diameter of Ø0.5mm. This would allow for low power settings and reasonably high power settings. The ideal for lower settings would be a smaller diameter nozzle and for high power settings a larger diameter nozzle, but Ø0.5mm is a good compromise.

• Clogging of the nozzle is a typical problem in these stoves and it stands to reason that a larger diameter nozzle would suffer less clogging. (Bussmann, Visser and Sangen, 1987)

Once the nozzle diameter is known the other burner dimensions can be found using the empirical expressions: “empirical expressions can be inferred. They relate the nozzle-burner head distance (h) and the burner head diameter (D) with the nozzle diameter (d). The expressions are given below:

Nozzle – Burner head distance:

\[ h = 17 + 122 \times d \text{ (mm)} \]

Burner head diameter:

\[ D = 15 + 67 \times d \text{ (mm)} \]

“The quality of the nozzles appeared to be extremely important both for the performance and for the safety of operating the stove. A burr in one of the nozzles caused the nozzle to form a cloud of kerosene vapour instead of a vapour jet.” (Floor, van der Plas, 1991:36)

Any particles entering the pressure stove system can cause blockages of the vapour jet nozzle. A potential solution for this would be to supply the user with adequate tooling to be able to perform repairs on the stove (i.e. removing the nozzle and cleaning it). The stoves also require a removable filtering system that would filter out particles within the fuel. The nozzle prickers supplied with the stoves tested are soft and can only really be used when the stove is
functioning under pressure. This can be dangerous, and in the laboratory testers experience doesn’t actually work very well. The pricker extinguishes the flame and the stove emits a fine cloud of paraffin vapour into the air, this continues until the pressure in the vessel is released. It is tempting at this stage to attempt to restart the stove. However, in the laboratory testing this proved to be quite dangerous. Furthermore, the nozzle blockage could be a result from the paraffin heating up too much in the vaporising chamber and causing the paraffin to develop burnt carbon particles before being released through the nozzle. It is very difficult to remedy this build up without being able to remove the vapour jet nozzle.

To summarise:

- Jet nozzles should be removable to be serviced outside of the stove.
- All stoves should be supplied with a tool to allow the user to remove the nozzle for general maintenance.
- The filling area and fuel line should include a filtration system to filter out particles to the vapour jet nozzle.

Other suggestions for better vapour jet nozzle performance include:

- The system of having wire rope in the vaporising fuel line of several of the camping stoves tested, apparently allows for turbulence in the fuel and vapour mixing area which reduces the carbon build up in the jet nozzle. More experimentation in this area should take place to try to reduce the amount of carbon build up.
- Work needs to be done to improve efficiency levels in paraffin burners. The camping stove burners appear to perform at higher levels of efficiency and power than the traditional burner systems, perhaps lessons can be learnt from this and a new burner could be developed.
- Furthermore, maintenance instructions for such a procedure should be supplied.
7.3.2. Lighting the stove:

Lighting of the low income household pressure stoves proved to be problematic for the user test group. However, all of the stoves were supplied with well designed light assists which in laboratory testing the testers found functioned well. A potential solution could be for the users to be provided with better instructions on how to light the stove. This could include photographic reference or decent pictograms and written instructions.

7.3.3. Extinguishing the flame and control of the stove:

The system of releasing pressure in the pressure paraffin stoves works well for flame extinguishing and is immediate. However, in camping stoves the controller which is generally placed below the burner is used to control the flame as well as extinguish the flame. This system cuts off the fuel supply rather than releasing the pressure. When shutting down the fuel, the camping stoves continue to burn for some time before extinguishing as a certain amount of fuel remains in the fuel lines or in the vaporising chamber and this needs to burn off before the stove stops working. This controller system however, works very well for the control of the flame at the burner end, as apposed to the pressure paraffin stove system of playing with pressure and release which appeared to be more difficult for the user test group to manage. However, the instant pressure release was able to shut the pressure paraffin stove down completely and immediately. Therefore any future design will need to consider both of these systems or develop a system that offers both functions.

7.3.4. Filling the stove:

Filling the pressure stoves is an issue. The user cannot see how full the stove is until it overflows and the filling orifice is very small. In addition to this impurities can be introduced to the sensitive vapour jet nozzle through the filling process.
Solutions for this problem could include:

- The filling orifice should be increased in size to allow filling with a standard bottle, rather than with a funnel system only.
- The stove may require a fuel gauge of some sort to indicate fuel levels when filling, however, with a larger filling orifice this issue may be resolved.
- A funnel that has a specific filtering function with a removable and cleanable filter system should be included with the stove. This needs to be of a much better quality than the system currently provided and must filter all particles of Ø0.3mm and larger.
- A filtering system could be fitted to the paraffin dispensing container. This could be used for filtering particle when filling the container at the retailer.
- The filtration system should also be of a material that is readily available and easy for stove owners to replace. Alternatively the manufacturer should set in place a system that allows for the supply of replacement parts.
- These filters should be multi-layered soft filtering materials that could capture fine grains of dust and impurities before they are introduced to the stove.
- An alternative is to build a filtering system into the stove, possibly at the base of the fuel feeder tube. This should be designed to capture particles before they reach the burner.
- All these solutions are required to be easily removed and cleaned.
- The funnel supplied with the stove should have one or more ribs on its side in order to prevent any air lock occurring when filling the stove.

7.3.5. Pressuring the stove:

The current system of having the pressuring pump mechanism permanently assembled to the stove makes pressuring the stove difficult and dangerous when the stove is alight. This is
because the pump mechanisms all seem to be faulty, are ill considered in terms of the ergonomic use, the pumps need a lot of pumping to reach working pressure and the pumps need continual maintenance.

Potential solutions include:

- The system of having the pump remote from the stove. There is potential to develop an attachment that could fit the current filling orifice thread and attach to a standard bicycle pump. The pump line needs to be long enough to prevent any shake and stability issues when pressuring the stove.

- The pumps should also have a maximum pressure release safety system to stop any over pressuring of the system. The pump should have a maximum pressuring capacity of 200kPa as testing has revealed that these types of stoves work well at between 50kPa and 150kPa.

- Separate the fuel vessel from the burner unit and have a fuel line running to the stove. Examples of this type of system include the Amazing Amanzi stove developed in conjunction with Eskom, or the principle of the two plate LPG stove.

7.3.6. Potholders, body construction and stove configuration:

The tripod foot configuration needs some consideration. Although the tripod system is functionally very good on rougher surfaces, the diameter of the footprint is too small. The standard configuration of pressure paraffin stoves is such that the stove, fuel vessel with burner on top with potholder above this, will always be unstable as the height versus footprint ratio is not good.

Suggestions for improvement for low income pressure paraffin stoves include:
• The potholder and stove body should be designed to allow for accurate placement of a pot on the stove, the diameter or footprint of this should be larger than the standard Ø225mm pot size.

• Heat transfer to the fuel vessel should be reduced. The design configuration should allow for shields or enough space between the burner and fuel vessel to reduce this heat transfer.

• The fuel vessel could be remote from the stove, allowing the burner to dictate the maximum height required for the stove.

• The stove footprint size could be increased to improve stability.

• The height of each of the pressure paraffin stove components should be reduced as far as possible without compromising fuel capacity, having serious implications on heat transfer and other functional aspects of the stove.

• A double pressure stove should be considered as most users require more than 1 cooking pot for an average meal. The possibilities for a 3 or even 4 plate stove should also be considered.

• The design of a free standing stove may solve the issues of where the user places the stove. This may also resolve problems of stability.

7.3.7. General pressure stove recommendations:

• Designers must consider a safety mechanism of immediately releasing pressure in the fuel vessel if anything goes wrong with the stove.

• If the stove is knocked over, the flame should be contained. If not, then the flame should immediately go out.
• The technical skills required to run and maintain pressure paraffin stoves need consideration. A simple system of regular maintenance should be encouraged. This maintenance should be described in the instructions supplied with the stove.

7.4. General Recommendations for both Wick and Pressure Paraffin Stoves

A couple of issues were noted as universal and would need to be resolved for both types of low income paraffin stoves. These included the supply of paraffin to users and the instructions supplied with the stoves.

Users cannot be trusted to use stoves as prescribed by manufacturers. All types of testing will be required to understand how users may interpret the use of the new stove once this has been designed. All of this information should be used to add safety features where necessary or eliminate and limit the users’ options where safety seems to be at stake.

7.4.1. Paraffin bottles:

If the system of supplying clean paraffin in child resistant containers, as indicated by Truran (2004b.), comes to fruition and is legislated then the issue of paraffin users using milk bottles and cooldrink bottles could be resolved.

However, if no such legislation happens, then I suggest the following recommendations:

• The onus should be on stove suppliers and manufacturers to include a child resistant container for the transport and use of paraffin in the home. This system should include the child proof cap or a similar device that prevents children under a certain age of accessing the fuel. It should also consider the age of children that may well need to use the fuel for cooking purposes such as in child headed homes and children cooking while parents work late.
• This container should have accurate markings on the outer surface for varying levels of paraffin. I suggest 250ml increments in order to ensure that the retailer supply the amount of fuel requested accurately and that the user can purchase a varying amount of fuel according to budget available specifically at informal retailers distributing the paraffin from 200 litre drums.

• The bottle should be semi-translucent for the users to see the quality of paraffin being supplied and possibly also any particles or impurities in the fuel.

• The bottles should be supplied with a cleanable filtration system to reduce the risks of particles being introduced to the more sensitive pressure stoves.

7.4.2. Packaging and instruction:
The requirement for the packaging and instruction needs to consider several factors in South African society. South Africa has 11 official languages and has a high illiteracy level. SAQA\textsuperscript{2} has a literacy level determining system called ABET\textsuperscript{3}. The written information supplied with the stove should be at an ABET level that suits the literacy level of low income users. From previous research it was shown that South Africa’s literacy level is reasonably low. Of adults over 20 years of age 10.3\% have no schooling and 16\% have only some primary schooling (Stats SA, 2007). It would be reasonable to deduce that the majority of these individuals are of the low income bracket.

The understanding of three dimensional drawings has not been fully investigated in some of South Africa’s diverse cultures. However, the use of photographs with a human model indicating the stove instructions may be more effective in communicating in instruction

\textsuperscript{2} The South African Qualification Authority (SAQA)
\textsuperscript{3} The South African Qualification Authority (SAQA) has developed the Adult Basic Education and Training (ABET) system of dividing reading and writing skill levels into 3 levels. With ABET Level 1 being equal up to Grade 3, ABET level 2 equal up to Grade 5, and ABET level 3 is equal to Grade 6 and above.
manuals. It would assist designers and manufacturers in future if a study were to be conducted in the understanding of pictographic and photographic instructional manuals.

From the testing it was felt that comprehensive instructions should be supplied. These instructions should include all aspects of using the stove safely. This includes assembling the stove correctly, filling the stove, lighting the stove, placing a pot on the stove, adjusting the stove settings, extinguishing the stove correctly, general maintenance of the stove, cleaning the stove and constructing special devices to make working with these stove easier (such as a home made light assist). The cost factors of printing excessively long instruction manuals could negatively affect the price of the final product. However, if the instruction manuals were printed along with selling graphics on the stove packaging this cost could be reduced.

In my opinion the written information supplied with the stove should be at ABET level 1, supported by pictograms or photographic instruction and should be delivered in languages with regional sensitivity because of the high illiteracy levels specifically amongst the low income market.

- Users did not tend to read instructions from the limited user testing conducted; they preferred to learn from one another. Any new stove should arrive with easy to understand instructions, but may also require vigorous education programmes to teach users how to use the stove safely and conveniently as a portion of the marketing campaign.

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4 At ABET Level 1 the individuals reading of texts should include: narrative, persuasive, factual and everyday information/practical texts.

The Examples given:
- a. narrative: stories, very simple readers, simple songs, personal letters, dialogues, drawings or photographs.
- b. factual: simplified information pamphlets.
- c. persuasive: simplified advertisements, posters, slogans.
- d. everyday information/practical: simple forms, lists, number combinations in everyday contexts (e.g. telephone numbers, date, times, prices), simple written instructions, calendars, simple recipes, letters, cartoons, simple messages, newspaper headlines, product labels, symbols (e.g. logos), and so on.” (SAQA CLS ABET 102)
• The use of regional languages needs to be included in any instruction leaflet.

• Instructions should include common terminology for components that make up the stove; alternatively a drawing and parts list should be included.

7.5. Conclusion

The recommendations given reflect the understanding gained from experimentation by the student testers and me. The inclusion of users in testing allowed me to understand a few more factors which add value to the recommendations shown. I do not believe that enough user testing has been completed to fully understand the user and their requirements for future stove design. The recommendations in this chapter would be better informed by more comprehensive user testing.

The market is in need of a cost effective stove that is safe and comfortable for all users. The largest proportion of users of these stove users are women and children. From experience gained during the testing and from the research completed within this project, I believe the largest potential product development project is for the development of safe wick stove. Wick stoves are less complicated and do not require technical finesse to resolve issues with nozzles, pressure pumps and filtration of paraffin. Wick stoves are relatively simple, can function with dirtier paraffin and are reasonably easy to maintain and repair. Also these stoves do not require specific high performance components and therefore could be manufactured relatively cheaply, but within safe parameters.