Appendix 4

Technical Report

Design and Construction of the

SOWTech UK Prototype eCook Stove

Contents

Preface

Context

The Appendix gives an account of the design and fabrication of the UK prototype of an eCook stove. Other appendices give more details of other technical aspects of the programme. These are as follows:

- *The development of the heating elements of the stoves*
- *The development of the Power Optimisation Device (POD) to manage the power generated by the photovoltaic (PV) panels*
- *The field trials of the Malawi eCook stove prototype*

This work was undertaken as part of a programme called Modern Energy Cooking Services-Technology Research for International Development (MECS-TRIID) managed by Loughborough University and funded by DIFD. The objective of this initiative was to fund research into developing new solutions and approaches which may improve the performance and delivery of modern energy cooking services and which will provide tangible and impactful benefits.

These appendices have been written to provide a full account of the work undertaken so that it may be disseminated and shared. The report includes pictures and diagrams explaining what has been undertaken but the technical text has been kept to a minimum. The account seeks to convey the areas where things have not gone according to plan as well as those that we are pleased to report, so that the full learning experience can be passed on.

The structure of the report

The work will be described as a series of discreet work packages with each package having a section which describes the what problem or challenge is being investigated. We see the path to our objective being achieved through a series of hurdles which needs to be overcome. These "hurdles" could also be referred to as steps on a pathway, or experiments, or research topics or tasks. In this report we will call them TASKS. Following the statement of each task there will be an account of the work undertaken. The work undertaken will contain a brief description of what was done. This is then followed by a short conclusion and comment on the implications arising from that work. The Implications may be conclusions or outcomes from research, further questions to be addressed or decision regarding what to do next.

The aim to make these accounts short and discreet so that they are easier to cross reference and to make it as easy as possible for easier for the reader to follow the evolution of the project.

TASK 1:- TO IDENTIFY THE DESIGN REQUIREMENTS FOR THE ECOOK STOVE

Introduction

The task is to interrogate the information obtained from literature research, the user-centred design work of this project and from technical discussion to determine the design parameters for this project.

Work undertaken

Meetings were convened within the project team which were used to establish a consensus regarding the execution of the project.

The work undertaken during the user centred design study were used as the basis of the conclusions. A review of energy storage options was undertaken.

Batteries for electricity

Plus points	Negative points
Familiar technology	Not suitable for deep cycles (full to empty)
Widely distributed	Cost
	Potential theft risk

Thermal storage in steel

Plus points	Negative points
Scrap steel available	Difficult to construct
"AGA Stove" model to emulate	Difficult to standardise
Cost	

Thermal storage in concrete

Plus points	Negative points
Familiar technology	Low heat transfer
Widely distributed	Hard to reach high temperature
`	Carbon footprint of concrete

Thermal storage in Phase Change Material

Plus points	Negative points
Known temperature output	Track record of use limited
Potential for scale	Availability in the short/medium term
Space efficiency of heat storage	
Low health hazard to users	
Positive reports from other projects	

Conclusions

The following summarise the design criteria to be used.

- *Cooking takes place during the day but two meals are prepared when PV power would not be readily available, breakfast and evening meal*
- *The foods that require most cooking resources are Nsima, (made from maize flour) and African beans. Nsima requires hot/usually boiling water and African beans require boiling water for toxin denaturing before being cooked for a significant length of time.*
- *It would be desirable to have two cooking plates so that both Nsima and beans could be prepared at the same time*
- *The possibility to charge mobile phones as part of the cooker facility would be a major asset with respect to market acceptability.*
- *Heat storage will be required to fully meet the objectives as solar energy is not available at the times when cooking is undertaken.*
- *The following table summarises the evaluation energy storage study*

Task 2:- Choosing a phase change material

There are many Phase Change Materials and the project needed select one to take forward for prototype trials.

Work undertaken

Phase Change Materials (PCMs) are substances which absorb or release large amounts of 'latent' heat when they change in their physical state, ie from solid to liquid and vice versa. This makes them capable of storing heat energy. They also need to be chemically stable and to be able to change from on phase to another many times without altering physically or chemically.

There are many compounds which meet this definition and they all have different properties. We undertook a review of scientific papers and Internet information which promote the use such materials for energy storage. (See Appendix 2). One option that we considered was high temperature paraffin wax but this was not the final choice.

The review identified a body of work which had been led by Prof Pete Schwartz of California Polytechnic Sate University (Cal Poly). It was not obvious from the reports which PCM was used, but personal contact confirmed that a compound known as Erythritol had been used. We decided that we should build on this work and use the same material in our trials. The Cal Poly work has been documented in You Tube as well as in scientific papers.

Conclusions

Erythritol was chosen as the PCM for the following reasons.

- *The heat emanating from the solidifying material is above the boiling point of water at around 118°C; a temperature which is higher than the boiling point of water.*
- *It is a mass produced product used as a weight control sugar substitute.*
- *It is readily available at a reasonable cost in retail quantities for trials and in bulk quantities if required.*
- *It is produced by fermentation so has the potential for local production.*
- *It is a registered food additive. It is safe to ingest so contamination of food by the PCM during cooking has no health risk implications.*

There is one possible drawback to the use of Erythritol. It is known to have the potential to supercool. That means that it looses its heat and gets colder than its melting point, but it remains liquid. (Wang et al, 2017 Supercooling suppression and thermal behaviour improvement of Erythritol as phase change material for thermal energy storage. Solar energy materials and solar cells, vol 171. Pg 60-71)

The implication of this conclusion was that practical assessment of the risk of supercooling was required to ensure that we could use it as a PCM in the eCook stove.

Task 3:- To determine if Erythritol would supercool in use

Introduction

There are references in the literature that Erythritol can sometimes behave as a supercool liquid. This means that it can cool below its melting point without solidifying. If this were to occur it would prevent the Erythritol from releasing its latent heat so it would not serve as a heat store. The outcome of this task was to find out if this would happen in our application.

Work undertaken

500g of Erythritol was placed in a pan and this was heated on a low heat using a domestic gas ring. The form of the Erythritol was a sugar like crystalline material. The crystals started to melt and form a transparent liquid. This melting then continued to spread through most of the pan.

A handheld infrared temperature probe was used to monitor the temperature in the pan. The pan chosen for the trial was a brown enamel so that it would give a better infra red reflection than a shiny stainless steel surface.

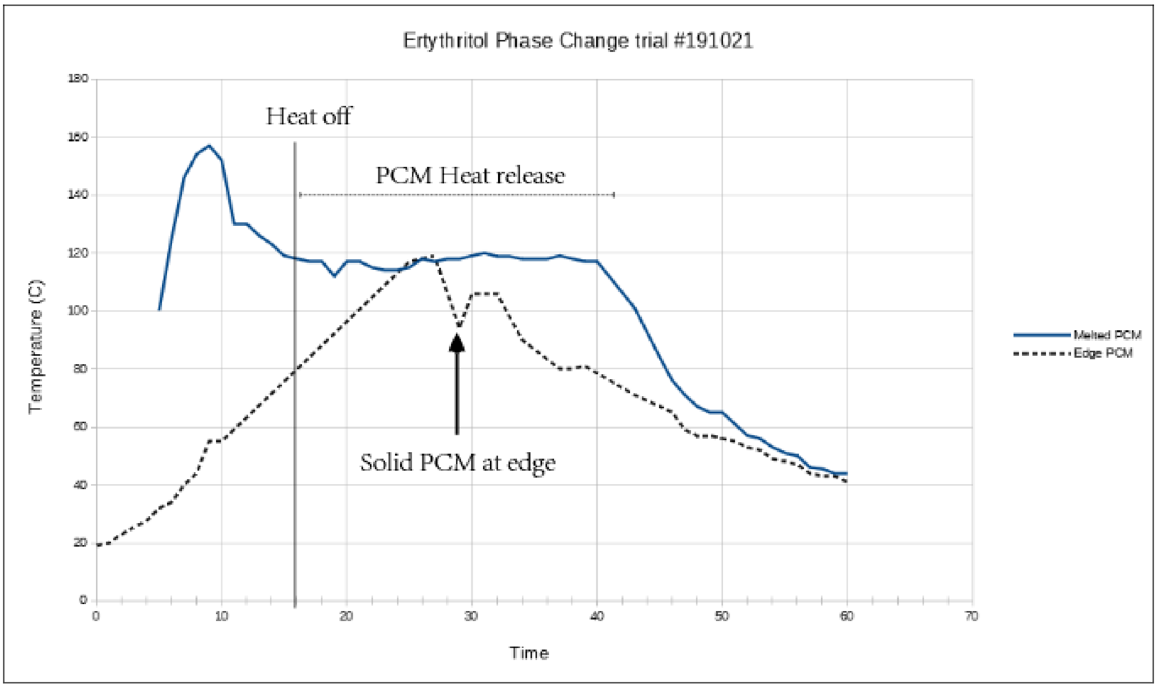
The material started to become hot (160°C) before some of the Erythritol at the edges were molten. The heating was terminated at this point and the liquor monitored as it cooled. The table below shows this trial data. Photo illustrations are also shown.

These temperature data show that during the cooling process there was a steady release of heat over a period of 25 minutes at temp 118°C. The temperature data are shown in the graph below. Photos are also included to show how the PCM melted in some places but not others.

Conclusions

The Erythritol cooled and solidified at a temperature around that of the melting point. There was no evidence of supercooling. The implication of this trials were that it was reasonable to continue to study the use of Erythritol as a PCM.

A further observation from this trial was that the PCM could be hot in one location and that only a centimetre or so away, the temperature could be over 50°C less. Heat transfer within the PCM could be an issue.



Graph showing the PCM change during heating and cooling. The flat line illustrates the period of heat release from the PCM. Photo below shows unmelted PCM alongside melted PCM at 150°C .

TASK 4:- TO CONDUCT HEAT FROM PCM TO THE HOTPLATE

Introduction

The initial trials showed that heat transfer capability would be a key part of the design of the eCook stove. The following account describes trials to explore how the PCM and the hotplate can be constructed to achieve effective conduction of heat.

Work undertaken

The work comprised of a series of "look see" trials which took place on a domestic induction hob. The following photos illustrate the trials. A brief account is given below

The first trials reproduced the experience of the initial experiments and confirmed the practical implication of the lack of heat conductivity within the PCM itself.

The second trial put two steel bolts from the centre to the edge to assess the use of a bolt to transfer heat from the hot centre to the cooler sides. The impact of the bolt in the unmelted PCM was limited to a few millimeters but it did melt it.

The third trial showed that a pan directly floated in the PCM could boil water. Whilst efficient this approach was provisionally rejected as PCM would be lost when the pan was removed from the eCook stove. In use there would also be a scald risk as the PCM was at 118°C.

The fourth trial used gravel as a support for the pan. Whilst the gravel did serve to ensure that all the PCM melted as heat was being transferred from stone to stone, it did not provide a good contact surface for a hotplate tile or the pan.

The use of sand was the fifth trial and that showed that the pore spaces within the sand were not large enough to allow sufficient PCM into the mix to provide the necessary heating capacity. The use of hot sand as a hotplate surface was interesting but not as a co-mix with the PCM.

Conclusions

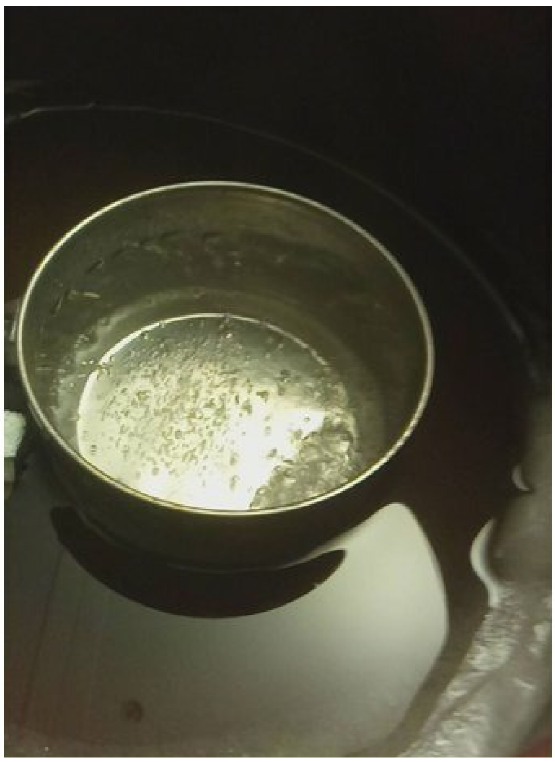
Although none of the approaches gave a clear indication of the best approach, it was decided that metal rods were the most promising approach to heat conduction to the hotplate.

Photo illustrations of Heat to Hotplate trials

#1 PCM melted in middle but not edges

#2 Steel bolts added as heat transfer rods

#3 Bolts had minimal impact to surrounding PCM

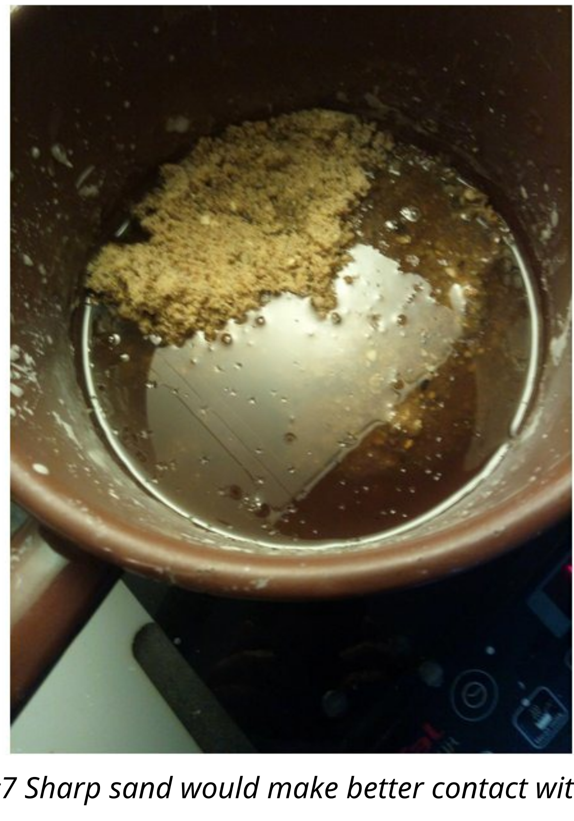


#4 Direct heating of bowl on top of PCM resulted in boiling water

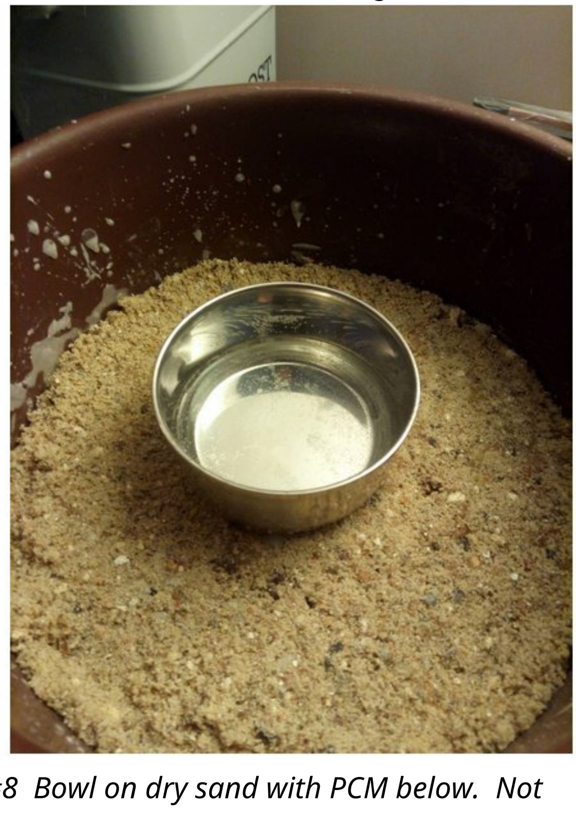
Photo illustrations of Heat to Hotplate trials cont.

#5 Gravel added a support for hotplate

#6 Tile on top of gravel was poor conductor due to minimal contact with gravel



#7 Sharp sand would make better contact with pan but pore spaces reduced PCM too much



#8 Bowl on dry sand with PCM below. Not enough PCM for heating

TASK 5:- TO ASSESS IF TOWERS MADE OF CANS CAN TRANSFER HEAT

Introduction

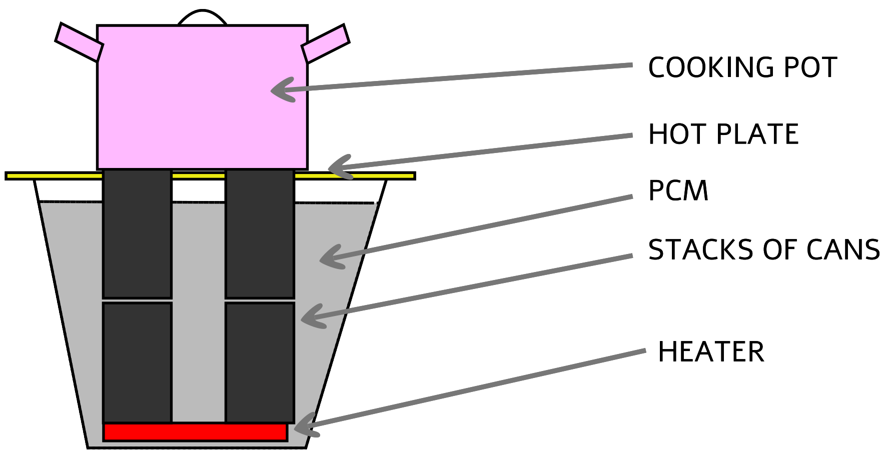
One of the ideas for "metal rods"for conduction of heat from the PCM to the hotplate considered was the use of steel food cans from the household waste. Old cans could be built into pillars and being metal would conduct heat. Waste food cans are widely available but they are limited in the volume of metal they contain, nevertheless it was felt worthy of investigation.

Work undertaken

Three towers of cans were constructed. The top three cans had their base removed and the tower assembled using fire-cement to join the cans together. They were tested as watertight, but were later found to be rather fragile. The three towers of two can each were used as the mount for the upturned frying pan which served as a hotplate.

The photo illustrations below show the method of assembly.

The diagram below illustrates the arrangement.



The can towers were then tested on the heaters to assess the capacity of the metal to provide a pathway for the heat. Once on the heated plates the cans were photographed using an infrared camera.

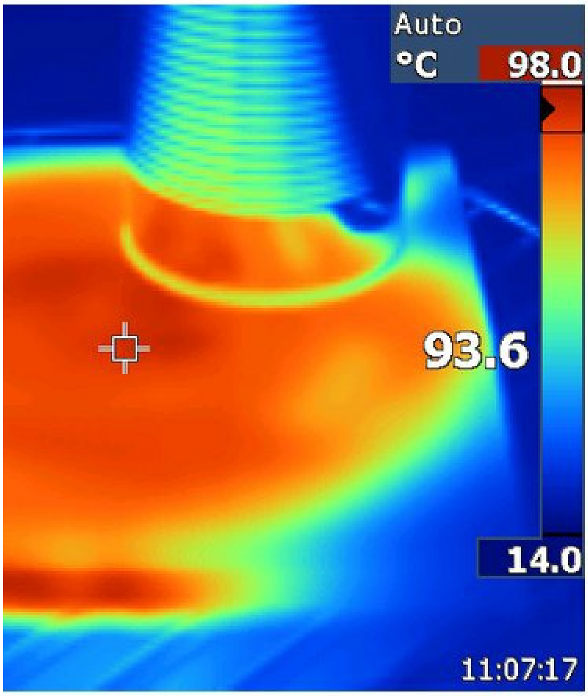
Conclusions

The conclusion from this work was that this was not a good option to pursue for two reasons. Firstly, although as a support for the hotplate they were strong, the pillars were structurally weak at the join and would need welding to made secure. The heating tests demonstrated that as conductors they were poor.

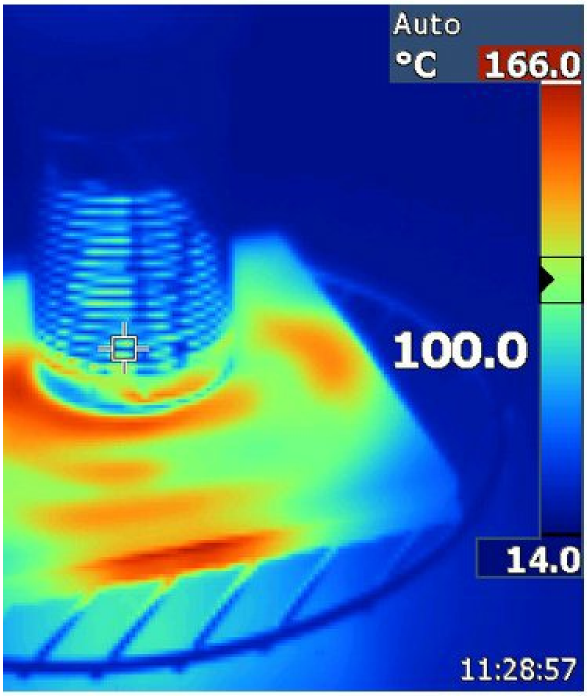
Photo illustrations of “can towers” trials

#1 Concept of can towers

#2 Three towers being water tested



#3 IR photo of can on heater tile showing that the heat transfer upwards is very limited.



#4 Second photo showing cool upper parts of cans

TASK 6:- TO DESIGN THE UK PROTOTYPE ECOOK STOVE

Introduction

Prior to building a the UK prototype eCook stove it was decided to prepare designs on the computer. The early trials had indicated that water could boil if it is in close proximity to molten PCM but the trials also showed that the PCM can be difficult to heat due to low heat conductivity. The trials have also highlighted the design challenge of getting the heat to the base of the cooking pot.

Work undertaken

Using Solidworks 3D computer aided design (CAD) an insulated box structure was designed. SOWTech sought advice during this process from its Malawi partners regarding access to materials to avoid using any materials that would not be suitable or available.

During the design phase there was consultation and discussion regarding the outcome of the user-design process undertaken earlier. For example, whilst a two hob cooker was desirable it was not felt necessary to include it in the design at this stage as a second hob could be incorporated later with minimal changes once the concepts had been established. Other issues such as mobile phone charging could be included now as they would be harder to incorporate later.

The output from the design process was some 3D visualisation drawings and a full pack of “for construction” drawings. This design pack was shared with the team. The illustration below shows one of the images from the design pack. It is not clear from the drawing but the upper part of the structure is a removable box lid. The lid void is big enough to house the pans commonly used in Malawi.

Conclusions

The response to the design pack was positive and it was considered appropriate to move into construction phase.

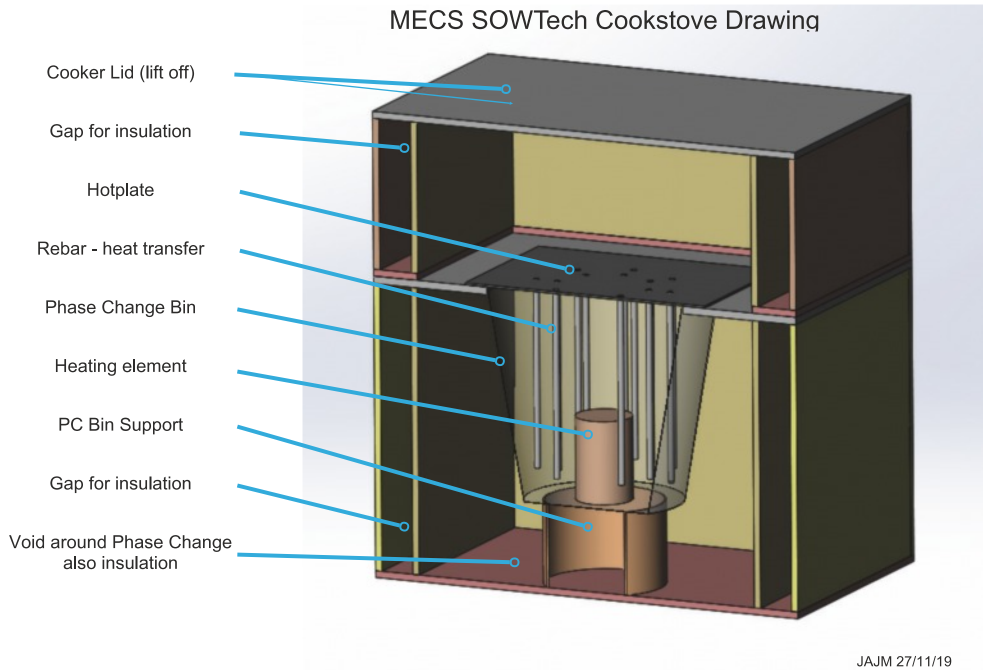
Comment

The issue of the form of insulation was challenging. Insulation materials in the UK are readily available, whereas in Malawi they are not. Furthermore the material that might be suitable for insulation in Malawi, such as rice husks, are not available in the UK. This challenge could not be resolved quickly so it was felt appropriate to progress using readily available UK insulation products and address the issue in Malawi during the field testing.

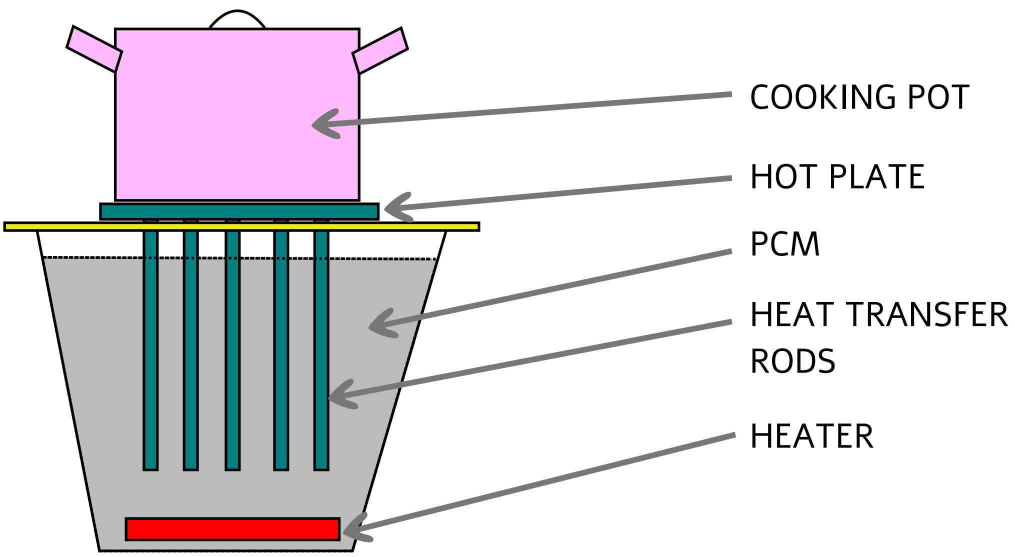
The development of the heaters meant that plate heaters would be used not can heaters but it would not cause significant changes to the overall layout.

The following photos illustrate the process of construction of the UK prototype.

Design drawings:- Photos overleaf



#1 Illustration of the 3D visualisation from the design drawings package



#2 Diagram showing the use of a plate heater instead of a can heater

Photo illustrations: building the structure

#1 OSM board and square section used to make the base box

#2 Metal waste bin used as the PCM vessel

#3 Rockwool wrapped around for insulation

#4 Photo of base assembly

TASK 7:- TO ASSESS HEAT TRANSFER USING COPPER TUBE PILLARS

Introduction

Metal rods to conduct the heat from the PCM to the hotplate was considered a good approach. The use of steel cans was discounted. Tubes made from old copper tube was tested next. The following trial was run to observe the performance of the arrangement.

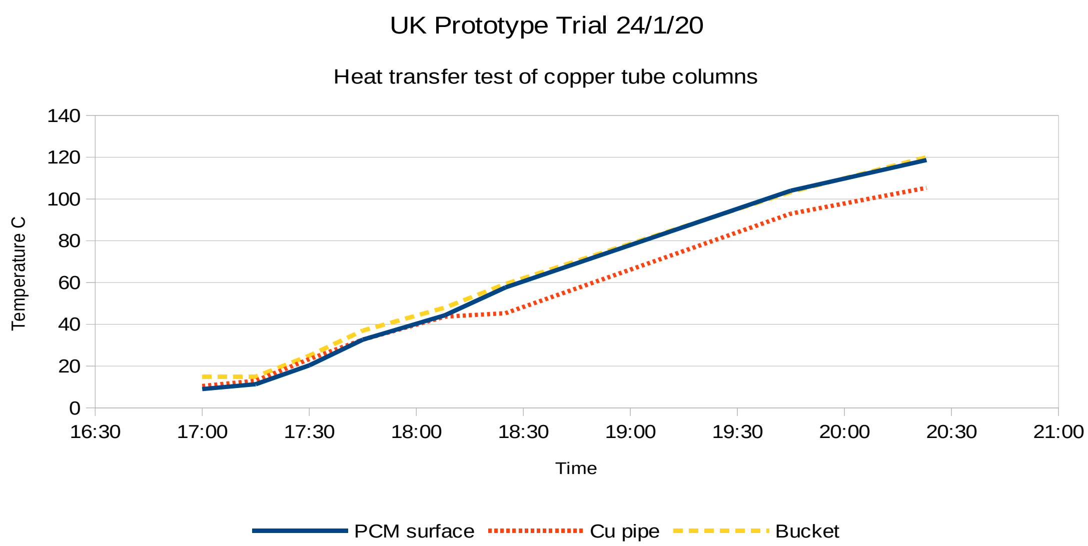
Work undertaken

The base unit of the cooker was assembled

Temperature readings were taken using the IR thermometer on the PCM surface, the surface of the bucket just above the PCM and the top of the copper pipe.

The graph of temperature readings show the close correlation between the heating of the PCM and the temperature at the top of the copper tube pillars.

These trials used the clay tile heaters and the power optimisation device (POD). Both units are subjects of separate appendices.



Conclusions

The close correlation of temperature between the PCM and the top of the copper pipe towers was encouraging. It was decided that further work would be undertaken with the arrangement as a stove. A further trial using the hotplate and a cooking pot was to be the next step.

The Power Optimisation Device (POD) and the clay heater tile worked as planned.

Photo illustrations of copper tube pillars

#1 Gravel used as spacer underneath the heater

#2 Clay heater tile on top of gravel

#3 Copper tube pillars held together with cable ties

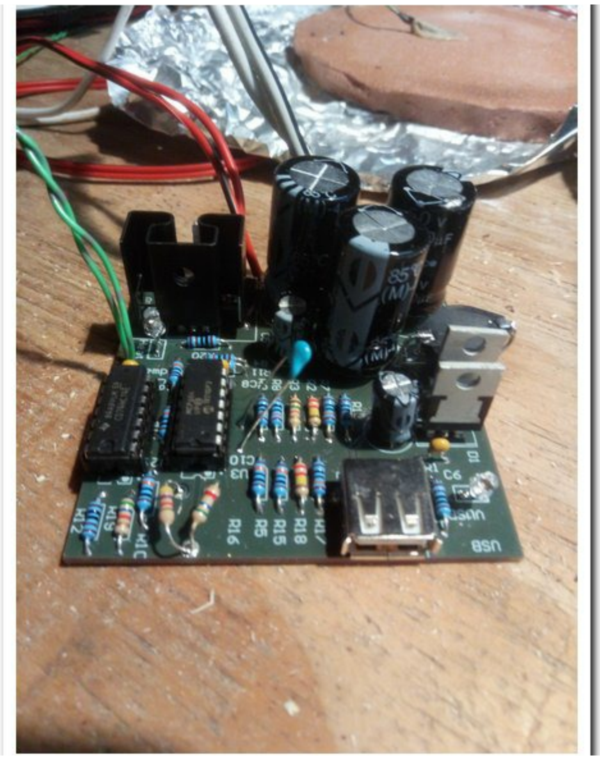
#4 Pipe pillars with gravel filled cant holding the copper pipes in position

Photo illustrations of copper tube pillars cont.

#5 The pillars in position in PCM bucket

#6 Pillars surrounded by PCM which has just started to melt

#7 Base assembly under test with temporary insulation on the top



#8 Showing the Power Optimisation Device (POD) providing power to heater

TASK 8:- TO TEST ECOOK STOVE USING COPPER TUBES PILLARS

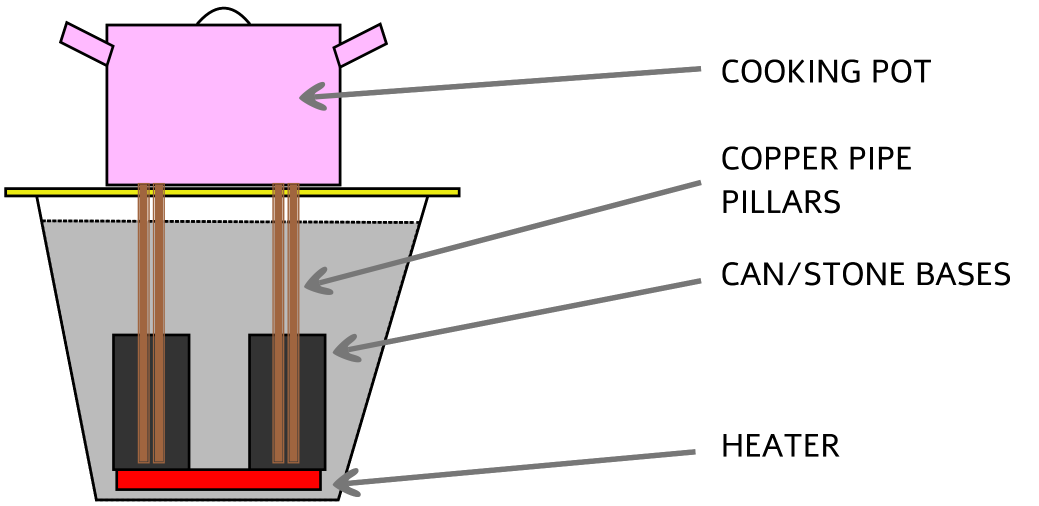
Introduction

The UK prototype cooker was constructed with few changes to the drawn plans. There were two exception to this. The use of rockwool meant that the double wall of the original design was not required. The double wall being necessary for loose fill insulation such as rice husks or vermiculite.

The second exception was that the rod based hotplate was not easy to build in the time available so an alternative using copper pipe rods and an upturned frying pan was used instead.

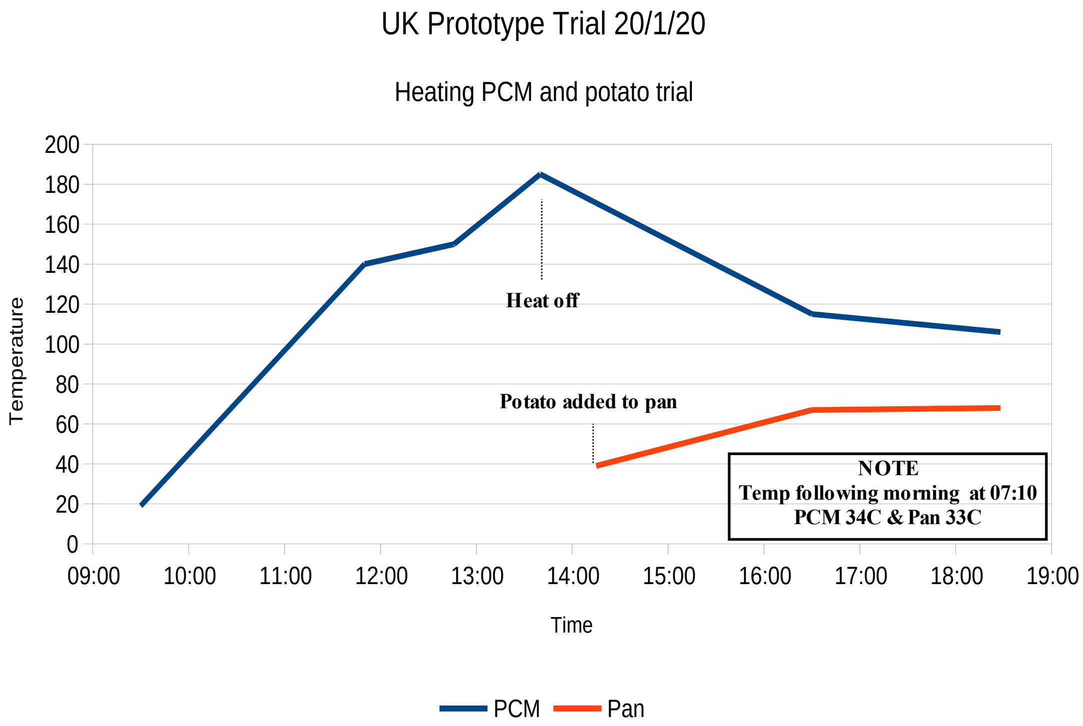
Work undertaken

The description of the assembly of the eCook stove structure is illustrated by the photos below. The trial used the copper pipe pillars as tested in the previous trial. A sectional diagram is given below.



The eCook stove was powered using the transformer and the POD as no solar power was available.

The temperature was monitored using oven thermometers - one in the oil and one in the pan. Inside the pan was placed a few potatoes to assess the cooking potential.



The temperature of the PCM was a cause for concern. The upper limit of the temperature should have been around 150°C but when it reached 180°C it was decided to terminate the heating. Subsequent investigations showed that the POD lights had been turning on/off as planned but the power to the heater had not been doing so. This was traced back to an earlier incident when the POD had been subjected to an accidental short and this had caused the component failure.

The other key important lesson arising from this trial was that it was also found that the heater plate had failed after being switched off. This then left the heater plate "icebound" in the PCM vessel and unable to be removed.

Conclusion

The outcome of the trial was a number of key lessons for future design.

The failure of the POD to accurately check the temperature mean that a second line of protection should be used. A thermal break would be included in heater wiring, which would melt at a preset temperature.

Once the PCM had cooled it became very difficult to recover the failed heater. Given that the heaters would be one of the most vulnerable components, it would be necessary to bring the heater out of the PCM by design, so that it could be recovered at will. The implication of this to the design was significant.

The potatoes which were placed in the eCook stove overnight were cooked the following morning. The eCook stove had no electrical power and the only heat was that released from the PCM.

Photo illustration of the copper tube cooker trial

#1 Hotplate temperature being recorded using IR thermometer

#2 Geotextile fabric being tested to absorb condensation and improve seals

#3 eCook stove lid and cooking pot on top of base unit

#Small potato used for trial. Cooked overnight in unheated eCook stove using only PCM heat

TASK 9:- TO ASSESS AN OIL BATH TO HEAT THE PCM VESSEL

Introduction

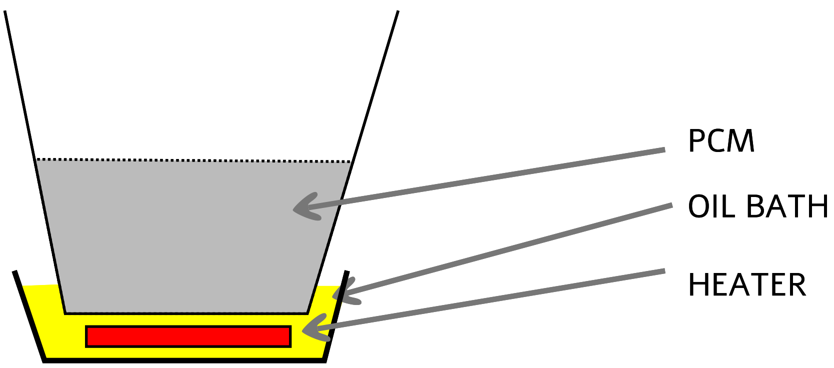
The risk of getting a heater trapped in solidified PCM requires an alternative arrangement to be developed. This trial is to assess the idea that a tray of oil might be an appropriate manner in which to conduct heat from the heaters to the vessel containing the PCM. The heater is in oil which in turn heats the base of the PCM vessel.

Cooking oil is readily available in Malawi.

Work undertaken

A washing up bowl was lined with fibreglass insulation and a stainless steel bowl mounted within the bowl. The PCM bucket bottom had a lip which would form an air lock when the stainless steel (SS) bowl was filled with oil. A tile and fire cement was used to fill this void so that the base was flush. The PCM vessel was placed into the SS bowl filled with a heater tile between the PCM vessel and the SS bowl. The thermistor was located in the vicinity of the heater tiles. The SS bowl was then filled with sunflower oil to a depth of approx 100mm.

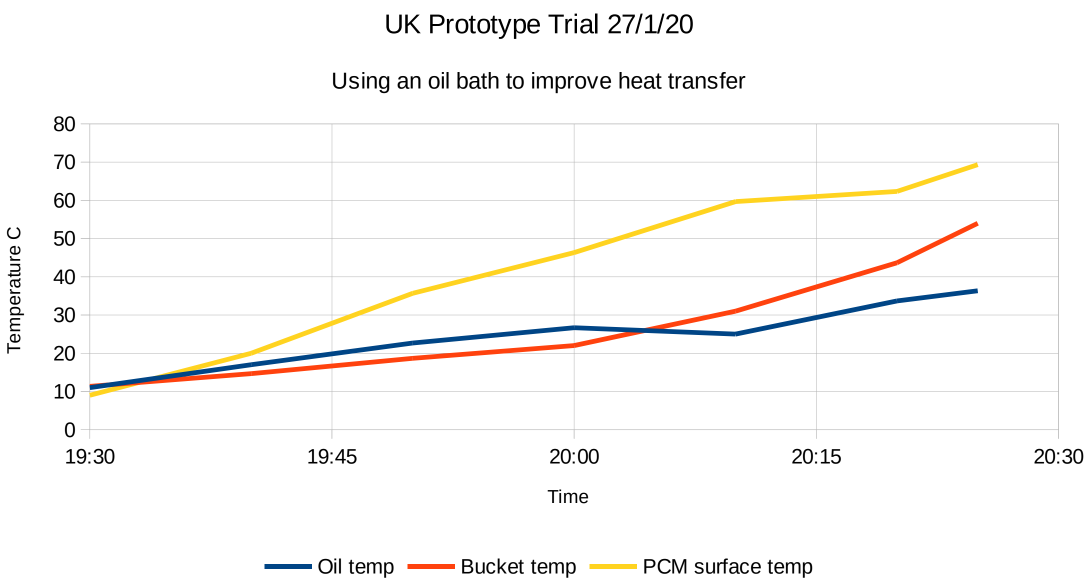
The diagram below illustrates the arrangement under test.



The near IR thermometer was used to measure the temperature of the PCM vessel just above oil level and the surface temperature of the PCM.

The following observations were made during the trial.

- *The oil boiled in the immediate vicinity of the heater plate. This was due to exposed wires remaining within the heater plate due to the method of construction*
- *The oil bath led to the PCM melting from the edges first, rather than from the middle when heated directly from beneath.*
- *The impression was that the oil bath was a big improvement on the heat transfer to the PCM vessel as shown by the speed and way the PCM melted.*



The trial of the oil bath was successful in transferring heat to the PCM vessel. Further ideas were developed during the trial and these led to an extension from the original objective. As oil and PCM are both immiscible and non reactionary, it might be possible to surround the PCM in oil and thereby enhance the overall heat transfer arrangements. So after some checks regarding the chemical properties of the two materials it was decided to investigate this further. The following actions were taken.

- *Some molten PCM was transferred to a clean food can. Vegetable oil was then added to the top of the molten PCM to determine if the two materials were immiscible. The relative bulk densities would indicate that this would happen, but a chemical interaction between the two compounds might occur.*
- *The observations were that the two liquids were highly immiscible. The PCM started to solidify below the oil level due to the cooling effect of the oil which was at approx 11°C .*
- *To test the use of vegetable oil as a heat transfer medium further, approx 600ml of sunflower oil was then added to the PCM in the bucket. This was then observed. The added oil on the surface of the PCM clearly facilitated the melting of the PCM on the surface of the vessel.*

Conclusions and implications

The oil bath improved heat transfer to the PCM vessel.

The thermistor needs to be mounted in a manner which retains the connection to the wire whilst being resistant to heating in oil.

The use of oil on the surface of the PCM improves the heat transfer into the PCM and aids in achieving consistent heating of the PCM.

The heater plate should not have exposed resistive wire or the exposed wire causes localised boiling of the oil.

The use of vegetable oil as a heat transfer media seems advantageous but the impact of the oil on the materials used to make the heater plates needs to be further investigated.

The oil and PCM are immiscible and do not react, leaving the option to fully enclose the PCM in oil.

The implication of this trial was that a oil bath outer vessel would effect heat transfer to the PCM. A twin vessel is now required, one which holds the PCM and one which holds the oil. This trial also suggested that oil not only below the PCM would be work, but perhaps the oil could completely cover the PCM. Could the PCM be covered on all sides, including the top. The bulk density of the PCM is higher than oil, but we needed to ascertain if the two materials interacted or reacted. If they did not react the use of a fully oil-enclosed PCM would ensure efficient heat transfer between materials.

Photo illustrations Oil being used as heat transfer mechanism

#1 Mortar filling the lipped to prevent an air pocket insulating the PCM bucket

#2 Tile heater trimmed to fit the base of the PCM bucket

#3 Spacers and tile heater placed in oil bowl and bucket placed on top

#4 Cooking (sunflower) oil added to the bowl

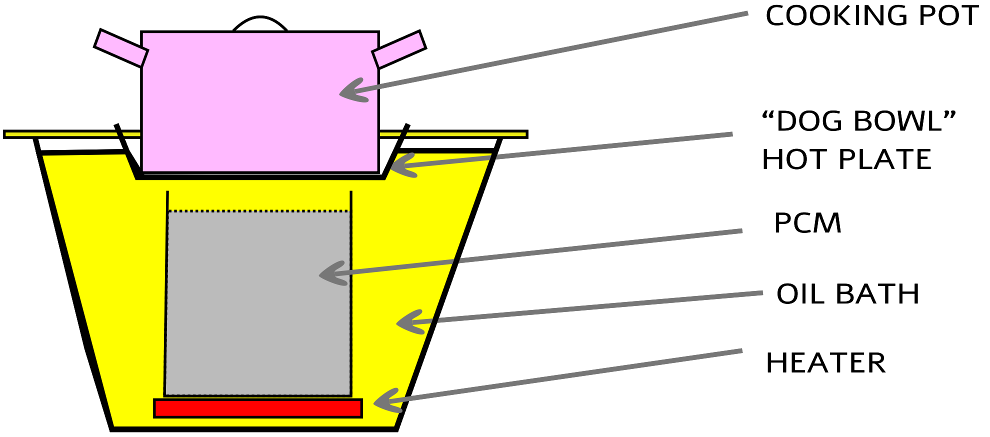
Task 10:- To improve the heat transfer using an oil immersed hotplate

Introduction

The purpose of this trial was assess the use of an oil immersed bowl as the hotplate for a cooking pot. The oil fully encapsulates the PCM which means that it can function as the heat transfer media for both the melting phase of the PCM and the freezing phase.

Work undertaken

A new arrangement for the internal core of the cooker was built and assembled as per the diagram below. The photos below illustrate how this was undertaken.



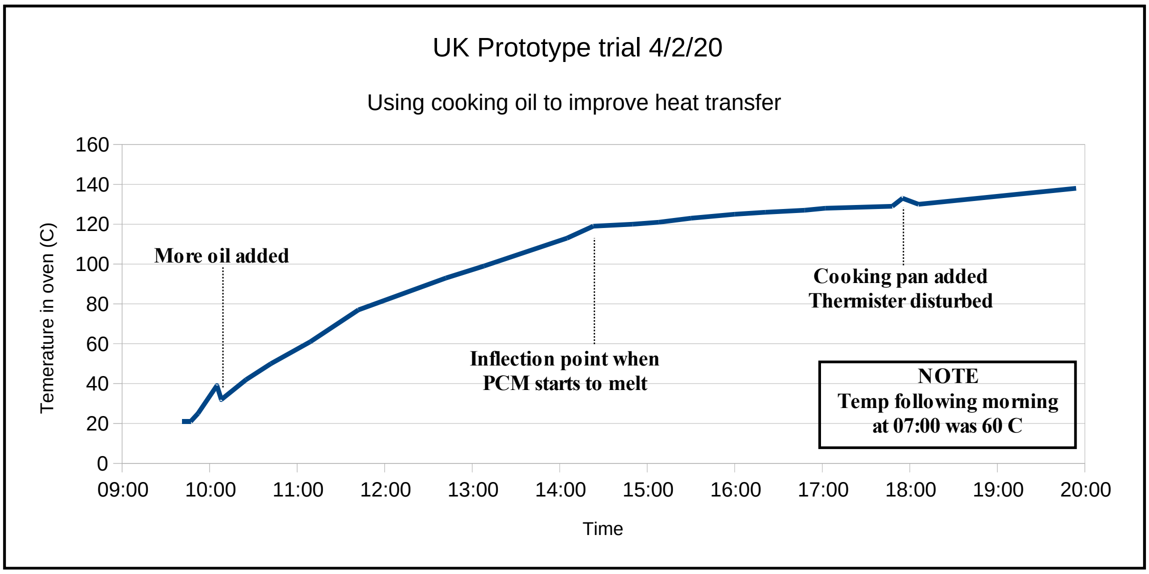
The only metal PCM vessel which could be procured was smaller than desirable but it did contain 2kg of PCM. The large volume of oil, (5 litres) meant that it took a significant period of time to heat up.

The graph below illustrates the temperature records.

At 6pm the cooking pan was added to the assembly which caused a disturbance in the oil giving rise to the blip in the heat profile.

The PCM did completely melt. The POD worked as planned and controlled the upper temperature.

The graph shows a clear inflection point where the PCM starts to melt and the rate of temperature increase drop as the heat is absorbed by the PCM.



Conclusions

The trial showed that PCM could be melted and to absorb heat, within 12 hours using the POD as the power source.

The POD temperature control feedback appears to be working as planned.

The use of oil stabilised the heat transfer process and gave rise to not "overheating" in the vicinity of the heater.

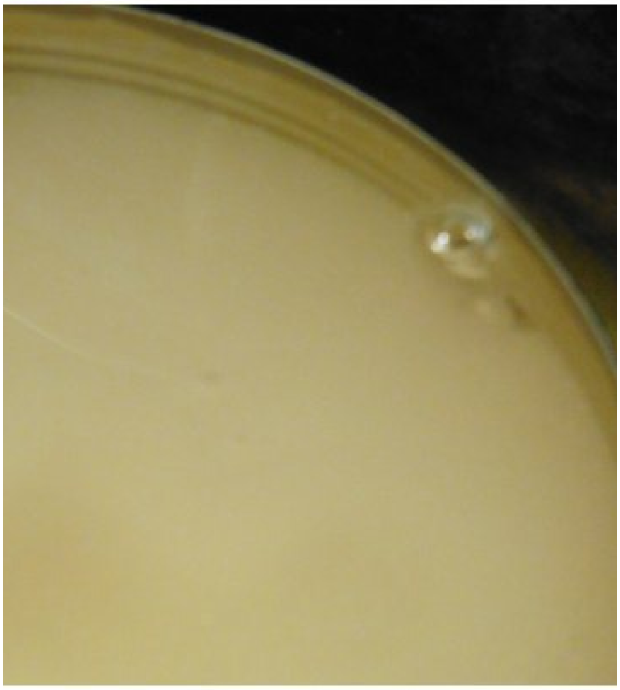
The oil immersed dog bowl has been the best approach used to date for heating the hotplate.

Photo illustrations

#1 Heater tile on spacers to allow oil circulation. PCM can on top of heater

#2 PCM being weighed into PCM vessel

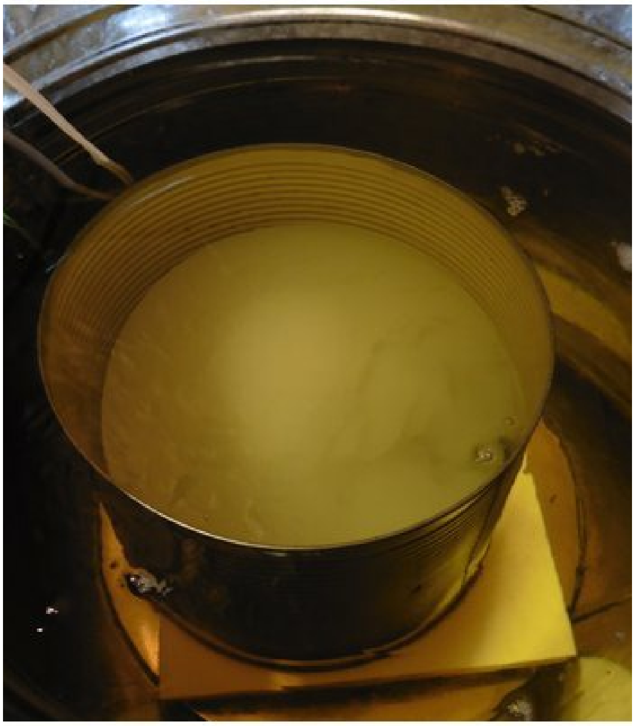
#3 PCM vessel within oil bath.



#4 Air being displaced by oil from the PCM. Top up oil needed after displacement

Photo Illustrations cont.

#5 PCM as filled for comparison with #6



#6 PCM partially melted - white powder visible below the melted layer (transparent) of PCM

#7 "Dogbowl" hotplate resting on PCM vessel within oil bath vessel.

#8 Boiling droplets of water on hotplate to illustrate temperature of hotplate

Task 11:- To test the oil immersed hotplate using maize flour

Introduction

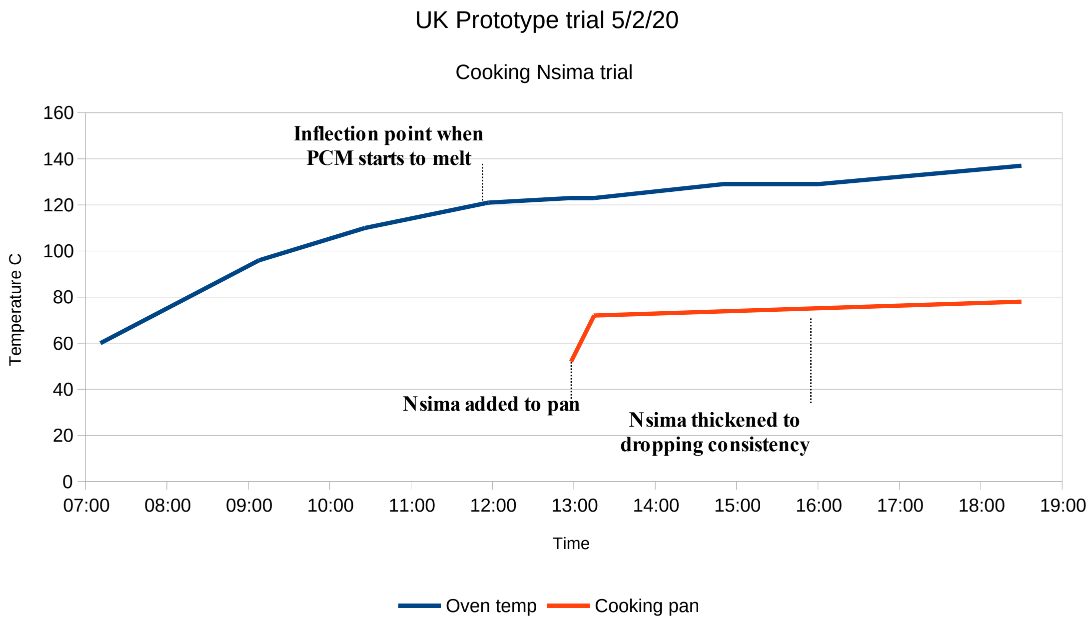
A key objective of the project is to be able to cook the type of food products eaten by the low income communities. Maize flour, which is turned into Nsima in Malawi, is one such staple foodstuff. This trial uses some Malawi maize flour and the apparatus described in the previous trial was used to heat the flour and water.

Work undertaken

The eCook stove was started whilst the oil was still at 60°C. The represents the retention of heat overnight. The eCook stove arrangement was the same as shown in the previous section.

When the eCook Stove was at an oil temperature of 123°C, a mix of flour and water was added to a lidded pan on the hotplate.

The following graph illustrates the temperatures of both the oil and the flour water in the pan.



Conclusions

It showed heat retention overnight with the temperature of the oil the following morning being 60°C and the cooking pan was 58°C. This is a temperature used for slow cooking which indicates that the oven could be used in this way overnight.

The use of the oil immersed hotplate did produce a temperature in the pan which was capable of changing the nature of the flour water mix to that of a solid.

The temperature that was achieved in the pan was disappointing. At the peak temperature of the oil (c 140°C) the pan temperature was still a lot lower at approx 80°C. Whilst this is well above the minimum temperature required for meat to be safely cooked, it is still well below the temperature required to boil beans.

This trial would indicate that the design can achieve a cooking temperature overnight, ie when un-powered. In other words the use of PCM delivered long term heat intput to the eCook stove. It can also achieve stable heating and oil temperatures which could be used for oil immersed cooked, ie deep fat frying.

The requirement to boil water for certain foodstuffs such as African beans has meant that the stove is currently unable to cook such products. However, we recognised the potential of the heater plates developed for the stove as potential hotplates for direct PV powered boiling of such food. Similarly we have also discussed the possibility of having a powered heater above the PCM as well as below it. Such an option would not dramatically increase the price but it could make a large difference to the potential of the unit to meet the needs of the market.

The following task was an initial test to explore this possibility. Further work along these lines was also undertaken during the field trials in Malawi. (See Appendix 7)

See overleaf for photo illustrations.

Photo illustration of the "Immersed bowl" trial.

#1 Pan in "Dogbowl" hotplate - insulated raised for the photograph

#2 Photo illustrating the lift off insulated lid above the base unit.

#3 Photo of the cooked maize flour showing the transformation of the starch into a solid texture.

Task 12:- To explore the use of the plate heaters as a stand alone cooking hotplate

Introduction

The objective of the project is to generate an eCook stove option which is made locally and which provides a means to cook the food eaten by those on low incomes. One of the foods which our target beneficiaries need to cook are African beans. These beans contain a toxin which needs to be boiled before it is safe to eat. After a period of boiling it is then cooked for a considerable period of time but boiling for this stage is not required.

This trial was a first "look see" to explore the idea that we could make a hotplate suitable for boiling water using the heater components which we had already developed, namely the POD to control the PV output and the heaters. This first trial is reported below

Work undertaken

The trial was started at 2pm on a winters day when there was some weak sun. The heater used to start the trial was a concrete tile heater as it has a flat surface suitable to good contact with a pan. However the tile was not oil conditioned and may have contained some residual water. At 97°C it "blew" the concrete so it was replaced with a clay tile, shown in the illustrations below.

The clay tile was placed on a piece of insulation board and a pan containing 300ml of cold water was placed upon it. After 50 minutes the water in the pan was at 60°C and the hotplate was approx 156°C .

The trial was terminated at this time as there was no further sunshine.

Conclusions

This little test gave encouraging results and indicated that a direct sunshine heated hotplate may be one way to achieve boiling. In this way the beans could be boiled during the day for the period of at least 10 minutes that are required to remove the Phytohaemagglutnin toxin but then be transferred to a slow cooking oven for the duration of the long cook which is over a matter of hours.

The following procedure has been recommended by the PHLS (Public Health Laboratory Services, Colindale, UK) to render kidney, and other, beans safe for consumption:

** Soak in water for at least 5 hours.*

** Pour away the water.*

**** Boil briskly in fresh water for at least 10 minutes**.*

The hotplate used in daytime sunshine could be a early simple system for achieving this critical cooking requirement.

Photo illustrations Hotplate trial

#1 Clay heater tile placed on insulation to act as hotplate

#2 Pan on tile which contains 300ml of water

#3 Solar panel in late afternoon winter sun (06/02/2020). Note plate heater is covered in fibreglass insulation to reduce heat losses. The oven thermometer display is visible on the fibreglass. The open POD is visible in the plastic box alongside.