DESIGN AND PERFORMANCE OF A CONOIDAL SOLAR COOKER

N. E. Wijeysundera and A. Sivapathasuntharam

1 Introduction

The concept of utilizing solar energy dates back to the eighteenth century, when solar cookers were constructed but their use restricted mainly to the inventor (Ref. 1). In recent times, such cookers have received widespread attention for use in sunny areas where there is a scarcity of conventional fuels.

Many solar cookers with a wide range of designs have been constructed and tested in the field (Ref. 2 and 3). However, economics and social habits have been the two most important factors affecting the marketing and widespread acceptance of these cookers.

Designs used for solar cookers can be divided into two main types: the optical concentrator type and the 'hot box' type. The latter employs an insulated metal box with one or two cover glass panes to trap the solar heat (Ref. 2). In this case the cooking utensil is placed inside the box. The concentrator type cooker employs an optical reflector for focussing the sun's rays on the utensil located at the focus. The more commonly used reflectors have a paraboloidal shape. Although, very high concentration ratios may be achieved with these, there are three major disadvantages of this type of reflector for cooking applications. These are (a) obtaining a good paraboloidal form for the concentrator requires a considerable degree of technical sophistication, (b) the performance of these reflectors is very sensitive to orientation and therefore the orientation mechanism has to be carefully designed and in operation the reflector requires very frequent attention and (c) the cooking utensil in this case is completely exposed and thus loses a good deal of heat to the atmosphere, especially if there is wind.

In the present paper we describe a conoidal solar cooker which is able to overcome some of the above disadvantages. The conoidal shape reflector can be easily fabricated out of cheap materials and the performance of this is relatively less sensitive to orientation errors. Also, the cooking utensil in this case is well shielded by the reflector (Figure 2) and therefore heat losses to the atmosphere are considerably reduced.

2 Principle of Operation

The reflector shown in Fgure 1 has a conoidal shape. A beam of solar radiation in the direction of the axis of the cone is brought to a line-focus along the axis. A cylindrical target placed co-axially with the cone will receive the radiation on its surface. If a single conical frustum is used to capture the rays in a given area of the beam, then the receiving vessel will have a long length. This may be overcome by having a number of frustums as shown in Figure 2. The apex angle of each frustum and its height may be chosen to focus the rays on a desired height of the cylindrical target. This will also improve the concentration ratio (area of beam/receiving area on target) for the system. With a single frustum, the highest intensity of radiation will be received by the upper part of the vessel, and this decreases towards the lower part. A heat distribution pattern of this type is unsatisfactory as it would not facilitate natural convection heat transfer in the contents of the vessel. This difficulty may be overcome, at least in part, by using the arrangement shown in figure 2. Here, the apex angles and heights of the frustums are chosen to increase the radiation falling on the lower part of the vessel.

Even in this type of arrangement the direct heating from the base of the vessel remains small. However this may be increased by providing an extension of the base of the vessel as shown in figure 1. The outer surface of the cylinder may be painted dull-black to increase the absorption of solar radiation. It is seen from figure 2, that the hot side wall of the cylinder is well inside the reflecting frustum and 'sees' the outer atmosphere only through a small angle. This reduces the radiation heat loss considerably and provides protection from wind, which in turn reduces the convective heat loss to the atmosphere.

3 Construction

3.1 *Reflector*

The conical frustums were fabricated out of 32 S.W.G G.I. sheets. The folded frustums were reinforced with metal rings at each end. As preliminary tests showed that the G.I. surface had a poor reflectivity for solar radiation, it was decided to apply aluminium foil on it as the reflecting material. With this arrangement it was found that the temperature of the reflecting frustum near the heated vessel, was only marginally above the ambient temperature. This led to the important realisation that even the cone nearest the vessel could be made out of

N. E. Wijeysundera, BSc (Eng), MSc, PhD, graduated from the University of Sri Lanka in 1966. He proceeded to UK in 1968, on a Commonwealth Scholarship and obtained his MSc in Reactor Physics and Technology at the University of Birmingham. He was subsequently awarded the PhD, by the same university for his work in the field of Nuclear Reactor Engineering. He is now Lecturer in Mechanical Engineering at the Faculty of Engineering, University of Sri Lanka, Peradeniya Campus. His main research interest is in the field of "Alternative Sources of Energy".

A. Sivapathasuntharam, BSc (Eng), graduated from the University of Sri Lanka in 1973 offering Mechanical Engineering group of subjects. In 1974 he supplemented his degree by qualifying in Civil Engineering subjects. Since graduation he has been an Instructor, Assistant Lecturer and is presently employed in the Department of Mechanical Engineering, Peradeniya Campus as a Research Assistant in the field of "Alternative Sources of Energy".

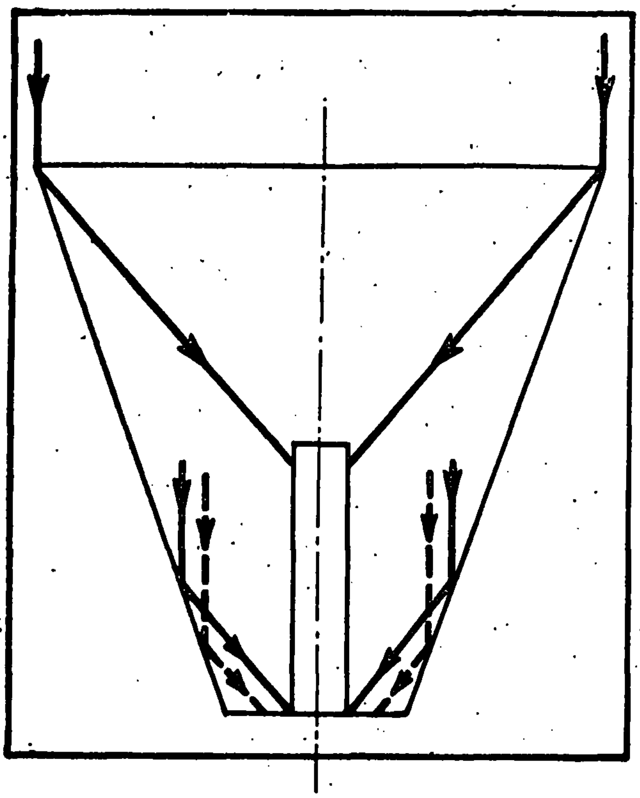

Fig. 1: Reflecting Conoidal frustum

material like cardboard and also, that no thermal insulation was required around this frustum. The frustums were assembled by fixing metal rods to their outer surfaces along the generators, and bent to the correct angles. This permitted the easy removal of a frustum when the heating had to be decreased. The dimensions of the reflector assembly used in the present test are indicated in Figure 2.

3.2 *Orientation Mechanism*

The orientation mechanism used is shown in figure 3. The reflector assembly and the heat receiving vessel are fixed to a light rectangular wooden frame which is free to turn about a horizontal axis. The unit was mounted on a wooden platform which could be moved about its vertical axis. As the reflector is light the orientation mechanism is made out of wood. Also the conical reflector is not very sensitive to orientation. Calculations indicate that a ten degree angular misalignment of the axis of the reflector with respect to the direction of the solar beam reduces the radiation falling on the target by a mere 15 percent. Hence the orientation mechanism need not be precisely designed and also, the reflector does not need frequent attention. This characteristic was quite evident during the tests. A disadvantage of this type of mounting is that the vessel needs to be tilted with the reflector. At low solar altitudes, this can result in the liquid inside the vessel spilling. However this can be overcome by using a longer height for the vessel than the design value.

3.3 *Heat Receiving Vessel*

The heat receiving vessels considered in the present design were all cylindrical in shape with their outer surfaces painted dull-black. These were made either of aluminium or G.I. sheet. Some tests were also done with a glass vessel and a black metal cylinder inside it. This functions like an immersion heater as most of the radiation is absorbed by the metal surface.

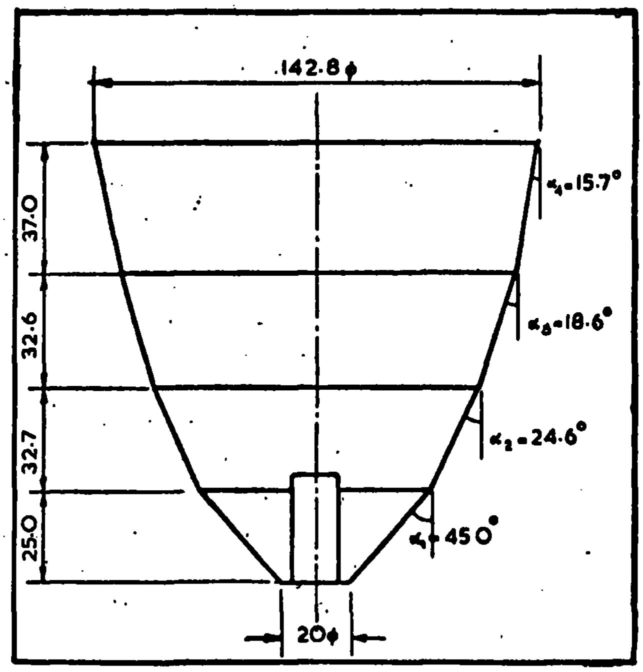

Fig. 2: Dimensions of present design in cm.

4 Performance Tests and Results

Field tests on the cooker were carried out at the Faculty of Engineering, Peradeniya over a period of about two months. The solar radiation was measured using an Eppley-Pyrheliometer and its output was recorded continuously on a Bristol chart recorder. The temperature of the vessel and its contents were measured using thermocouples, the output of which was also recorded on a Speedomax-16 channel temperature chart recorder. The unit was orientated by observing the image of a thin rod located parallel to the axis of the reflector.

Results of tests carried out on a number of days with different reflector and vessel arrangements are summarized in Table 1. The time taken to boil 2 litres (0.44 gallons) of water is taken as a measure of the thermal performance of the cooker. This was done partly to compare the present results with tests on other types of solar cookers already reported in the literature (Ref. 1 and 3). The average efficiency for the cooker is defined as the ratio of the total heat absorbed by the water to the total solar radiation falling of the cooker during the time of heating.

It is seen from Table 1 that the average efficiency of the conoidal cooker varies between about 20 percent and 40 percent. The efficiency of heat collection depends on the following factors: (a) the reflectivity and orientation accuracy of the reflector, (b) the weather and the condition of the sky during heating, (c) the heat losses to the surroundings by convection and radiation and (d) the heat absorption of the vessel. Factor (a) can be kept constant during the trials but factors (b), (c) and (d) are variables which cannot be controlled during different trials. Variation in factors (b), (c) and (d) will partly account for the wide variation in the average efficiency of the cooker.

It is seen that cloudy spells of over about five minutes usually result in longer 'water heating times' and also smaller cooking efficiencies. The heat transfer to the water is greatly reduced during the period following a cloudy spell. This is because the vessel absorbs most of the heat which falls initially, before heat is transferred to the water. The effect will be less pronounced for the light aluminium container than for the G.I. container.

The results also indicate the variation to be expected in the performance of the cooker in actual practice. It is seen that an area of 1.14 m- i.e. 3 frustums would be adequate for a practical cooker with a capacity of about 600 watts.

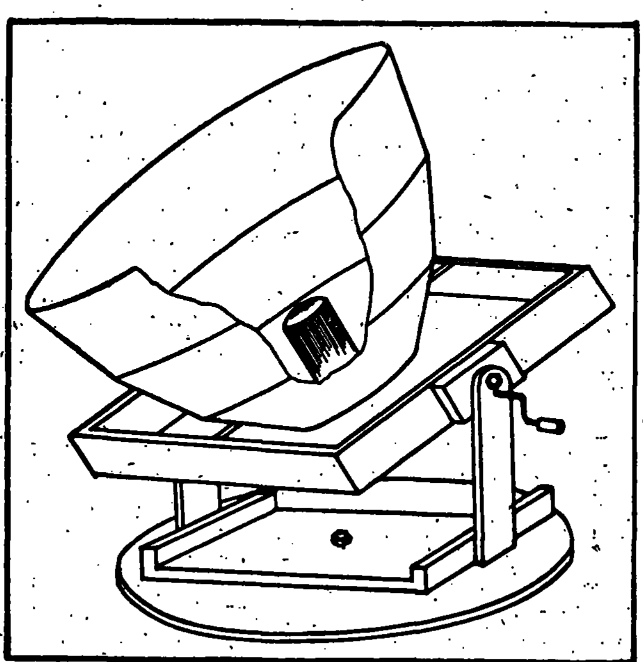

Fig. 3: Cooker and orientation mechanism

The efficiency of the present cooker is lower than the efficiency of 70 percent reported by Tabor (Ref. 3) for one using concave mirrors, with a high reflectivity. The performance of this is better than the umbrella-type reported by Lof[1], with an efficiency of around 25 percent. The good performance of the present design is mainly due to reduced heat losses to the surroundings. However, a direct comparison of tests done at different locations is not always accurate because of the variability of the weather and sky conditions between the locations.

5 Conclusion

The design, construction and field testing of a conoidal solar cooker was described. Field tests carried out under varying sky conditions indicated that the average efficiency of the present cooker was comparable to other designs reported in the literature (Ref. 1 and 3). The largest cost component of the present design was the reflector assembly which is made out of G.I. sheet metal with aluminium foil as reflecting material. It was clear during the tests that this could be easily fabricated out of cardboard with aluminium foil for reflector surface, as it is not subject to high temperatures. This modification will result in considerable reduction in the cost.

Two important performance aspects of the cooker have to be studied over a longer period of time. These are: (i) the durability and ageing of the reflector material and the resulting effects on the performance and (ii) the adaptability of the present design to various domestic cooking processes. These aspects of the conoidal reflector are now being investigated.

Acknowledgements

The authors wish to acknowledge with thanks the assistance given by the Laboratory staff of the Mechanical Engineering Department of the Peradeniya Campus in carrying out the present work. Some useful discussions with Drs. C. L. V. Jayatillake and S. Sivasegaram are also gratefully acknowledged.

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TABLE 1

Projected area of cooker m^2	*Type of vessel*	*Ambient temperature* °F	*Time Taken to boil 2 litres of water min.*	*Conditions of Sky*	*Average isolation Cal/cm²/min.*	*Average efficiency*
1.57	G.I. cont.	88.0	18.0	Slightly cloudy	1.40	39.3
1.57	G.I. cont.	87.0	29.3	Cloudy	1.30	26.7
1.57	Immer. Heat.	88.0	17.8	No clouds	1.44	33.3
1.14	G.I. cont.	87.0	24.2	Slightly cloudy	1.30	43.2
1.14	G.I. cont.	87.0	28.0	Shading for 4 minutes ...	1.36	36.4
1.14	G.I. cont.	90.0	37.0	Shading for 13 minutes ...	1.48	25.0
1.14	G.I. cont.	91.0	49.0	Cloudy for 30 minutes ...	1.14	21.8
1.14	Al. cont.	97.0	27.5	No clouds	1.18	37.4
1.14	Al. cont.	96.0	65.0	Very cloudy	1.03	22.2
1.14	Immer. Heat.	94.0	25.0	Slightly cloudy	1.26	34.6
1.14	Immer. Heat.	90.0	27.0	Clear sky	1.03	40.7
1.14	Immer. Heat.	88.0	32.0	Shading for 4 minutes ...	1.23	41.0
0.754	Immer. Heat.	87.0	44.0	Slightly cloudy	1.26	28.5

Immer. Heat. ... Immersion Heater type container
G.I. cont. ... Galvanized Iron container
Al. cont. ... Aluminium container

කේතු-හිරු කිරන ලිපක පිරිමැවුම සහ ක්‍රියාකාරිත්වය

එන්. ඊ. විජේසුන්දර සහ ඒ. සිවපාතසුන්තරම්

මෙම ලිපියේ කේතු-හිරු කිරන ලිපක පිරිමැවුම, නිර්මාණය සහ ක්‍රියාකාරිත්වය විස්තර කෙරේ. බොහෝන් පරීක්ෂණ වලට භාජනය කොට ඇති පරාවලයික පරාවර්තකය හා සසඳන කල, කේතු පරාවර්තකය සෑදීමේදීත්, භාවිතයේදීත් විශේෂ වාසි කිහිපයක් ඇත. කේතු හැඩය, තලයක් නැමීමෙන් පහසුවෙන් සාද ගත හැක. කේතුවේ අක්ෂයත්, සූර්ය විකිරන දහරත් අතර කෝණික එකෙල්ලේ දෝෂයක් තිබෙන කලද, ලිපෙහි කාර්යක්ෂමතාව අඩුවන්නේ කුඩා ප්‍රමාණයකිනුයි. තවද, මෙහි පිසින භාජනය පරාවර්තකයෙන් වැසී ඇති හෙයින් එයින් වායුගෝලයට සිදුවන තාප හානි අඩුවේ.

කේතු පරාවර්තකය 32 SWG ගැල්වනිත යකඩයෙන් සාද ඇති අතර, ඇලුමිනියම් පරාවර්තක ද්‍රව්‍ය ලෙස භාවිතා කොට ඇත. පිසින භාජනයේ උස අඩුකර ගැනීම සඳහාත්, එය මත පතිත වන විකිරනය හැකි තරම් දුරට ඒකාකාරව තබා ගැනීම සඳහාත්, කේතු චින්නක කිහිපයක් සමක්ෂකව තබා ගැනීමෙන් ලිප නිර්මාණය කොට තිබේ.

ජලය ලීටර් 2 ක් නටන උෂ්ණත්වය දක්වා රත් කිරීමට ගතවන කාලය, ලිපෙහි ක්‍රියාකාරිත්වයේ දර්ශකයක් ලෙස සැලකිය හැක. මෙම ලිප භාවිතයේදී මේ සඳහා ගත වන කාලය වලාකුලු අඩු දිනකදී, මිනිත්තු 25 ක් පමණි. විද්‍යාත්මක ලිපි ලේඛණ වල සඳහන් වන වෙනත් හිරුකිරන ලිප් පිරිමැවුම් හා සසඳන කල, මෙම ලිපෙහි කාර්යක්ෂමතාව සතුටුදයක යයි සැලකිය හැක. තවද, මේ ලිපියේ සඳහන් වන ප්‍රතිඵල අනුව මෙම ලිප, කාලගුනය වෙනස්වන කල ක්‍රියාකරන ආකාරය පැහැදිලිව පෙන්නුම් කරයි.

கூம்புருவக சூரிய அடுப்பின் விதானமும் அதன் சாதனையும்

என். இ. விஜெசுந்தர — அ. சிவபாதசுந்தரம்

பொழிப்பு:

கூம்புருவக சூரிய அடுப்பின் விதானத்தையும் அதன் சாதனையையும் பற்றி இக்கட்டுரை விவரிக்கிறது. விரிவாக ஆராயப்பட்டுள்ள பரவளைவுத் தெறிகருவியுடன் ஒப்பிடும்போது இக்கூம்புருவக தெறிகருவிக்கு அமைப்பிலும் செயலிலும் சில முக்கியமான அனுகூலங்கள் உண்டு. தட்டையான தகட்டை எளிய முறையில் வளைப்பதால் இக் கூம்புருவக உருவம் இலேசாகப் புனையப்படலாம். மேலும் மற்றைய தெறிகருவிகளுடன் ஒப்பிட்டுப் பார்க்கும்போது இவ்வகைத் தெறிகருவி தனது சாதனையில் குறிப்பிடத்தக்க அளவு குறைபாடு இல்லாமல் பெரியதிசை விலகல்கோணத்திற்கும் இடம் கொடுக்கக்கூடியதாக இருந்தது. மேலும் இங்கு சமைக்கும் பாத்திரம் தெறிகருவியினுள் இருப்பதால் அது காற்றிலிருந்து பாதுகாக்கப்படுகிறது.

அலுமினியம் மென்தகட்டை தெறிபொருளாகக் கொண்ட இத்தெறிகருவி 32 S.W.G., G.I. தகட்டினால் ஆக்கப்பட்டது. ஒரு தரப்பட்ட கதிர்ப்பரப்பில் கதிர் வீசலைப் பிடித்துக்கொள்ள ஒரே ஒரு கூம்பு பாவிக்கப்பட்டால் இதற்கு மிக நீளமான வெப்பம் பெற்றுக்கொள்ளும் பாத்திரம் தேவைப்படும். மேலும் சூடாக்கல் பாத்திரத்தின் மேற்பகுதியில், கடுமையானதாகவிருக்கும். இதைத் தவிர்ப்பதற்கு வெவ்வேறு உயரங்களையும் சிகர கோணங்களையும் கொண்ட கூம்பினடித்துண்டுகள் ஒரு பொது அச்சில் அடுக்கிப் பாவிக்கப்பட்டன. கறுத்த மை (பெயின்ற்) பூசப்பட்ட உருளைவடிவான பாத்திரத்தில் கிட்டத்தட்ட சம வெப்பப் பரப்புதல் இருக்கக்கூடியதாக கூம்பினடித்துண்டுகளின் உயரங்களும் சிகரக் கோணங்களும் தெரியப்பட்டன.

2 இலிற்றர் தண்ணீரை கொதிக்க வைப்பதற்கான நேரம் அடுப்பின் சாதனை சுட்டியாகக் கொள்ளப் பட்டது. தெளிவான நாளில் இவ்வடுப்பிற்குரிய வினைத்திறன் முன்னைய வெளியீடுகளில் கூறப்பட்டுள்ள அடுப்புகளுடன் ஒப்பிட்டு பார்க்கையில் நன்றாக இருக்கிறது. வெவ்வேறு வானநிலையிலும் கால நிலையிலும் பெறப்பட்ட பெறுபேறுகள் அடுப்பின் சாதனையைக் காட்டுகின்றன.