Development of Standards for Solar Concentrating Cookers

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PRINCE (Promoters, Researchers & Innovators in New & Clean Energy)

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Why different Test Standard for Concentrating Cookers?

1. Pot is open and not covered by greenhouse, hence radiation loss exists.
2. Water which evaporates leaves the pot and takes latent heat with it.

Design philosophy for proposed Test Standard for Concentrating Cookers?

1. Observations are taken at boiling point, which is very close to actual operating situation.
2. Instead of sensible heat gain measurement, latent heat measurements are done. Less error proneness, very few equipments required and very few observations required.
3. Normalised values of Heat rate and thermal efficiency are reported.
4. Normalisation of solar radiation and also for heat losses is carried out.
5. Optical efficiency is measured and not calculated.

Design philosophy for proposed Test Standard for Concentrating Cookers

Useful Energy = Solar energy input – Losses

Normalised heat rate

Normalised to Ibn=700W/sqm

Normalised to temp. diff. 75 °C (100 – 25)n

On the same lines normalised efficiency is also reported

Validating Test Standard

10 solar community cookers of 4 sqm each; PRINCE-40 paneled design were tested at different engineering colleges as student project in different location and different seasons.

Results of these align in close range validating the proposed test standard.

Proposed Test Standard

1. **Optical efficiency test:**
   - **Time of test: 10.30 to 15.30**
   - **Blackened open pot to be used**
   - **Water quantity 5 kg/sqm**
   - **Operating range of test : 10**˚C below ambient to 10 ˚C above ambient.

Proposed Test Standard

1. Optical efficiency test:

Calculate average value of I_{bn} over test period.

Input energy = Avg. I_{bn} (Watts/sqm)*Aa*T/1000 in kJ

Aa is aperture area in sqm

T is time in seconds.

Heat Gain = $Q_o = M_p * C_{pp} * (T_{wf} - T_{wi}) + M_w * 4.187 * (T_{wf} - T_{wi})$ kJ

Optical efficiency = η_0= Heat gain*100/Input energy in %

Proposed Test Standard

2. Thermal Performance Test

- Unique feature is that the observations are carried out at boiling point, which is close to operating point of the solar cooker.
- Measurements are taken near quasi-equilibrium status.
- Simple measuring equipment required.
- Error proneness is very low.

Proposed Test Standard

2. Thermal Performance Test

- How test is performed: Predetermined quantity of water, 2 kg per sqm, is used for the test.
- Once the water reaches boiling point, the pot with water is weighed and put back on the focus and then allowed to boil for one hour.
- Loss of weight of water in one hour due to evaporation, i.e. latent heat gain is taken as measure of heat gain.

Proposed Test Standard

2. Thermal Performance Test

- New method provides useful information like **heat rate** and **thermal efficiency** at boiling point of water.
- Observations are taken and performance reported near operating point and not extrapolated.
- To nutralise effect of solar radiation and ambient temperatures **normalised values are also reported.** This brings uniformity in reporting irrespective of location and climate.

Proposed Test Standard

2. Thermal Performance Test

Mass of water evaporated in one hour = $M_e = M_{wi} - M_{wf}$

Heat gain during one hour $Q_g = M_e * h_{fg}$ kJ

Input energy Q_i = Avg Ibn $*A_a*T$ /1000 in kJ

T in seconds (3600 seconds)

Thermal efficiency measured in field condition =

η_{th} = Heat gain*100/Input energy in %

Proposed Test Standard

2. Thermal Performance Test: Reporting normalised values

Authors recommend temperature difference of 75°C (boiling point around temperature 100°C & ambient temperature around 25°C) and I_{bn} of 700 Watts/sqm as standard operating conditions and all results are to be normalized to these values.

Proposed Test Standard

2. Thermal Performance Test: Reporting normalised values

a. Losses = Optical heat gain – Thermal heat gain

$= Q_o - Q_g$

b. Normalised Heat gain = Q_N

$$Q_N = Q_o * 700/I_{bn} - \text{Losses} * 75/(T_b - T_{amb})$$

c. Normalised Efficiency = η_N

$$\eta_N = Q_N / 700 * Aa * 3600$$

Proposed Test Standard

3. Fuel Saving Test

- Tests will be carried out on solar cookers as well as on competing/complementary technologies for boiling & evaporating same quantity of water.
- Test will provide apple to apple comparison with conventional cooking technologies using LPG, Wood etc.

Proposed Test Standard

4. Cooking Test

- Test will report physical suitability of test for cooking.
- Chicken eggs are taken as a reference being most commonly used all over the world. 6 eggs per sqm is taken as a reference.
- Hard boiling of egg is the criteria.
- Fuel saving per hour of operation of solar cooker is reported.

Proposed Test Standard

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Proposed Test Standard

5. Kitchen Performance Test

- Test is used for evaluating fuel saving potential in real life situation for any project. This data can be used for emission reduction potential.
- For target beneficiaries solar cookers are to be installed for few families/communities. Fuel consumption, before and after is to be recorded to understand real life impact. This is a vital data as such measurements incorporate real life inefficiencies and cultural practices.

Proposed Test Standard

6. Reporting other parameters

- Report may incorporate other parameters of interest, which may be measured or just observed. These include: Tracking frequency, tracking manual or automated, time to boil, installation, DIY kit, reflector details, packing size, weight etc. Most of these are parameters of interest for the prospective buyer.

Conclusions

a. Concentrating solar cookers need different test standards.
b. Proposed tests like Thermal performance test, Fuel saving test and cooking test can become the important tests for any 'Test Centers'.
c. Fuel saving test and cooking test will be of interest to prospective beneficiary organisations.

Conclusions

d. Fuel saving test and Kitchen performance test (KPT) will be of interest to compare performance of solar concentrating cookers with other conventional cook stoves. This apple to apple comparison will be useful for policy makers like GACC (Global Alliance for Clean Cookstoves), UNDP (United Nations Development Programs) and for governments especially in Asia and Africa. Data generated from KPT can be used for generation as well as validation of projects for CDM and similar carbon trading mechanisms.

Thank You.

Questions & queries welcome.

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