Annex 2

Indian Standard on Solid Biomass Chulha-Specification CIS 1315 Z (Part 1): 1991[1]

Annex A (Clause 11.1), Test For Thermal Efficiency

A-1 Thermal Efficiency

A-1.0 Thermal efficiency of a chulha may be defined as the ratio of heat actually utilized to the heat theoretically produced by complete combustion of a given quantity of fuel (which is based on the net calorific value of the fuel).

A-2 Conditions for Carrying Out Thermal Efficiency Test

A-2.1 Test Room Conditions

A-2.1.1 The air of the test room shall be free from draughts likely to affect the performance of the chulha. The room temperature shall be 25$\pm$5^{o}C at the beginning.

A-2.1.2 At the start of the test, the chulha and the wood being used shall be at room temperature.

A-3 Equipment

A-3.1 Instruments and Other Accessories:

a) Bomb calorimeter.
b) Mercury in glass thermometers 0-100^{o}C) {see IS 2480 (Part I) with solid stem/other temperature measuring device with the accuracy of $\pm$0.1 $^{\circ}$C.
c) Single pan balance 1 kg capacity (dial with least count of 10 g.).
d) Measuring jars; 1-1, 2-1 and 5-1 capacity.
e) Stop-watch or time measuring device.
f) Pairs of tong, metallic tray and sticks, etc.
g) Piece of clean cloth.

A-3.2 Fuel and Its Preparation

2.1 The fuel shall be *Kail/Deodar/Mango/Acacia* cut from the same log into pieces of 3x3 cm square cross-section and length of half the diameter/length of combustion chamber so as to be housed inside the combustion chamber. The fuel pieces shall be dried by the following method:

1/ Bureau of Indian Standards. Manak Bhavan, 9 Bahadur Shah Zafar Marg. New Delhi 110 002. October 1991.

a) Weigh total quantity of wood (say '*M*' kg.).
b) Pick up one piece and mark '*X*' by engraving and take its mass (say '*m*' g.).
c) Raise the temperature of oven up to 105°C.
d) Stack the wood pieces in a honey comb fashion inside the oven.
e) Maintain the oven temperature at 105°C.
f) After 6 hours, remove the marked '*X*' piece, weigh it and note reduction in mass from '*m*' g, if any. If reduction is observed put the marked piece in the oven again and repeat the weighing of '*X*' marked piece after every subsequent 6 hours period till the mass is constant and no further reduction in mass is observed.
g) At this stage, weigh the total quantity of wood and note loss of mass from '*M*' kg.
h) Determine the calorific value of the prepared wood with the help of bomb calorimeter.

A-3.3 Determination of Burning Capacity Rate

If the fuel burning rate per hour is not given by the manufacturer, the method described below shall be used to estimate the burning capacity of the chulha.

A-3.3.1 Stack the combustion chamber with test fuel as described in A-3.2 in honey comb fashion up to 3/4 of the height or in a pattern recommended by the manufacturer.

A-3.3.2 Sprinkle 10 to 15 ml. of kerosene on the fuel from the top of chulha/fire box mouth.

A-3.3.3 Weigh the chulha with fuel, let the mass be M_1 kg.

A-3.3.4 After half an hour of lighting weigh the chulha again and let the mass be M_2 kg.

A-3.3.5 Then calculate the burning capacity of the chulha as heat input per hour as follows:

Heat input:
per hour = 2 (M_1 - M_2) x CV kcal/h

Where
M_1 = the initial mass of the chulha with test fuel in kg.

M_2 = the mass of the chulha, after burning the test for half an hour in kg. and

CV = calorific value of the test fuel in kcal/kg.

(**Note:** this weighing applies only to portable metal stoves)

A-3.4 Vessels

The size of the vessel and the quantity of water to be taken for the thermal efficiency test shall be selected from the table given below, depending upon the burning capacity rating of the chulha as determined in A-3.3.

Aluminium Vessels for Thermal Efficiency Test (Clause A-3.4)

Sl No.	Heat Input Rate kcal/h.	Vessel Diameter (Ext) mm (±5%)	Vessel Height (Ext) mm (±5%)	Total Mass with Lid g (±20%)	Mass of Water in Vessel kg.
1.	Up to 2,000	180	100	356	2.0
2.	2,001 " 2,800	205	110	451	2.8
3.	2,801 " 3,200	220	120	519	3.7
4.	3,201 " 3,800	245	130	632	4.8
5.	3,801 " 4,200	260	140	750	6.1
6.	4,201 " 4,800	285	155	853	7.7
7.	4,801 " 5,400	295	165	920	9.4
8.	5,401 " 6,000	320	175	1,100	11.4
9.	6,001 " 6,600	340	185	1,200	12.50
10.	6,601 " 7,200	350	195	1,310	14.00
11.	7,201 " 7,800	370	200	1,420	16.00
12.	7,801 " 8,400	380	210	1,530	18.00

A-4 Procedure

A-4.1 Take the test fuel according to burning capacity rating for one hour. Divide the test fuel in 4 equal lots. Let the mass be '*X*' kg.

A-4.2 Stack the first lot of test fuel in the combustion chamber in honey comb fashion or as indicated by the manufacturer.

A-4.3 Select and weigh the vessel with the lid and stirrer in accordance with the table above. A minimum of two such vessels in a set will be required. Put the recommended quantity of water at 23 ± 2°C (f_1).

A-4.4 Sprinkle measured quantity '*X*' ml. (say 10 - 15 ml.) of kerosene for easy lighting on the test fuel and light. Simultaneously start the stop watch.

A-4.5 Feeding of fresh test fuel lot shall be done after every 15 minutes.

A-4.6 The water in the vessel shall be allowed to warm steadily till it reaches a temperature of about 80°C, then stirring is commenced and continued until the temperature of water reaches 5°C below boiling point at a place. Note down time taken to heat the water up to final temperature (less than 5°C below the boiling point) f_2°C.

A-4.7 Remove the vessel of A-4.6 from the chulha and put the second vessel immediately on the chulha. Prepare first vessel for subsequent heating.

A-4.8 Repeat the experiment by alternatively putting the two vessels taken in A-4.3 till there is no visible flame in the combustion chamber of the chulha. Note down the temperature of the water in the last vessel. Let it be f_3°C.

A-5 Calculations

A-5.1 Thermal efficiency of the chulha shall be calculated as follows.

A-5.1.1 *(In SI Units)*

If: w = mass of water in vessel, in kg;
W = mass of vessel complete with lid and stirrer, in kg;
X = mass of fuel consumed, in kg;
c_1 = calorific value of wood, in kcal/kg;
x = volume of kerosene consumed, in ml;
c_2 = calorific value of kerosene, kcal/kg;
d = density of kerosene, g/cc;
f_1 = initial temperature of water in °C;
f_2 = final temperature of water, in °C;
f_3 = final temperature of water in last vessel at the completion of test, in °C; and
n = total number of vessels used.
(Specific heat of aluminium = 0.896 kJ/kg°C).

(1 kcal = 4.186 8 kJ)

Heat utilized = $(n - 1)\ (W \times 0.896 + w \times 4.186\ 8)\ (f_2 - f_1)$
$+ (W \times 0.896 + w \times 4.186\ 8)\ (f_3 - f_1)$kJ

Heat produced = $4.186\ 8\ [(X \times c_1) + (xd/1000 \times c_2)]$kJ

Thermal efficiency, percent ( ) = $\dfrac{\text{Heat Utilized}}{\text{Heat Produced}} \times 100$

$$= \frac{\{(n - 1)\ (W \times 0.896 + w \times 4.186\ 8)\ (f_2 - f_1) + (W \times 0.896 + w \times 4.186\ 8)\ (f_3 - f_1)\} \times 100}{4.1\ 868\ \{(X \times c_1) + xdc_2/1000\}}$$

A-5.1.2 *(In Metric Units)*

If: w = mass of water in the vessel, in kg;
W = mass of vessel complete with lid and stirrer, in kg;
X = mass of fuel consumed, in kg;
c_1 = calorific value of wood, in kcal/kg;
x = volume of kerosene consumed, in ml;
c_2 = calorific value of kerosene, kcal/kg;
d = density of kerosene, g/ml;
f_1 = initial temperature of water, in °C;

f_2 = final temperature of water, in ^oC;
f_3 = final temperature of water in vessel at the completion of test, in ^oC; and
n = total number of vessels used.
(Specific heat of aluminium = 0.214 kcal/kg^oC)

Heat utilized = $(n - 1)\ (W \times 0.214 + w)\ (f_2 - f_1) + (W \times 0.214 + w)\ (f_3 - f_1)$ kcal

Heat produced = $[(X \times c_1) + (xd/1000 \times c_2)]$ kcal

Thermal efficiency, percent ( ) = $\frac{\text{Heat Utilized}}{\text{Heat Produced}} \times 100$

$$= \frac{[(n - 1)\ (W \times 0.214 + w)\ (f_2 - f_1) + (W \times 0.214 + w)\ (f_3 - f_1)] \times 100}{[(X \times c_1) + (xdc_2/1000)]}$$

A-5.2 Power Output Rating

The power output rating of a chulha is a measure of total useful energy produced during one hour burning of fuelwood. It shall be calculated as follows:

Power output rating = $\frac{F \times CV \times}{860 \times 100}$ kW

Where
F = quantity of fuelwood burnt, kg/h;
CV = calorific value of fuelwood, kcal/kg; and
= thermal efficiency of the chulha, as calculated above.

Annex B (Clause 11.2), Test for Combustion Efficiency

B-1 CO/CO_2 Ratio Measurement

B-1.1 Equipment

B-1.1.1 The chulha shall be tested with its grate filled with fuelwood equivalent to 1/4 of the burning capacity of wood as determined in A-3.3. Before starting the test, a vessel of the type and size as described in A-3.4 and containing water sufficient for the test shall be placed over the chulha. In addition, a collecting hood (see Fig. 5) suitable for the chulha under examination shall be used.

B-1.1.2 The hood shall be so designed that, while not interfering in any way with the normal combustion of the chulha, it collects a fairly high proportion of the flue gases. Also it shall be such that the sample collected represents the whole of the combustion gases and not those from one particular point. When using the hood, the damper provided shall be set, or additional flue pipe added, so that spillage of the flue gases around the skirt is minimized.

B-1.2 Procedure

B-1.2.1 With the hood in position over the chulha under investigation, the fuelwood shall be lit as given in A-4.1 to A-4.5 till a stable flame is achieved and the kerosene is completely burnt, then a sufficient number of samples shall be collected.

B-1.2.2 Any of the recognized methods may be used for gas analysis. For carbon monoxide, it is recommended that co-indicator of prescribed accuracy or the iodine pentaoxide method or catalytic method, for example the Drager method, Katz method, or infra-red analysis may be used. Carbon dioxide may be tested with Orsat apparatus, Haldance apparatus or by the infra-red analysis.

B-1.2.3 Each chulha shall be tested separately. The carbon monoxide and carbon dioxide contents of the product of combustion shall be determined by the methods capable of an accuracy of 0.001 percent and 0.05 percent, respectively of the volume of the sample.

B-2 Test for Total Suspended Particulate Matter (TSP)

B-2.1 Equipment

B-2.1.1 To determine total suspended particulate in ambient air, a Handy sampler is used. The Handy sampler consists mainly of an impinger (transparent nozzle type), a filter holder, filter paper (Gelman GN-4, 37 mm and 64678 or its equivalent Whatman) and a motor unit (which involves rotameter and suction pump). These accessories of the instrument shown in Fig. 6.

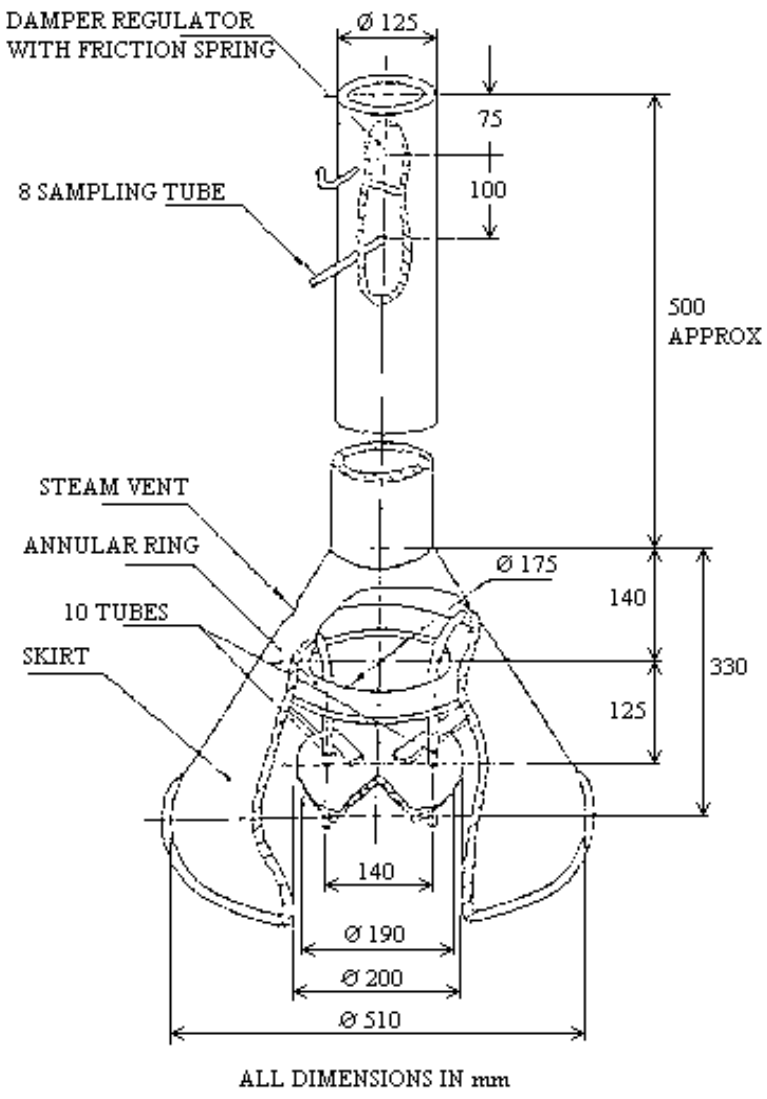

Figure 5: Hood for CHULHA

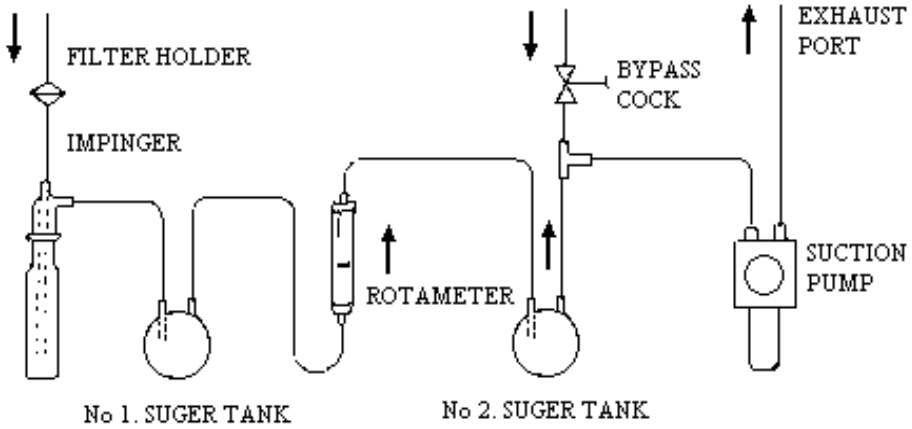

Figure 6: Flow Diagram for Handy Sampler

B-2.2 Preparation Before Operation

Filter paper (very neat and clean) is very carefully weighed on an electronic balance having an accuracy of 0.01 mg. and is placed between a filter holder. The filter holder and No. 1 surge tank (as shown in flow diagram) are connected to the impinger and the other arrangements of the accessories are checked out as per the flow diagram.

B-2.3 Procedure

Timer can be set for desired sampling time. It is set for one hour. Sampling time can be set to various times within 60 minutes by turning the knob clockwise. The flow rate of suction of ambient air is set by a rotameter, which can be used up to 2.5 l/min, maximum, for the purpose of this specification. The instrument maintaining the conditions described above is placed at a distance of 30 to 45 cm from the burning chulha and at a height of 30 to 37.5 cm from the ground level of the chulha. After the completion of one hour the filter paper is taken out and is again weighed on the same electronic balance, on which it was weighed initially.

B-2.4 Calculation

The total suspended particulate matter is computed by measuring the mass of collected particulates and the volume of air sampled in the ambient air, in the following manner:

If: Initial mass of filter paper in g. = X
Final mass of filter paper, in g. = Y
Flow rate of ambient air, litre/min = Z

(Flow rate zl/min is to maintained for 1h).
Then the mass of collected particulate, in g.

$= (Y - X) \times 1000$ mg.

Total volume of air $= Z \times 60$ l $= 60Z$ l

$= \frac{60Z}{1000}$ m^3 (since 1000 l = 1 m^3)

Total suspended particulate $= \frac{\text{Mass of collected particulates (mg)}}{\text{Volume of air sample } (m^3)}$

$= \frac{(Y - X)\ 1000 \text{ mg}}{60\ Z\ m^3/1{,}000}$

$= \frac{(Y - X) \times 10^6}{60Z}\ \frac{mg}{m^3}$

Annex C (Clause 11.3.1), Method of Measurement of Surface Temperature

C-1 Preparation of Chulha

C-1.1 The chulha shall be operated at the full output for one hour before starting the measurement of temperature, with the vessel containing water placed over it.

C-2 Procedure

C-2.1 The temperature of all parts of the chulha which are likely to be touched during cooking operations shall be measured by using a thermometer or any other suitable device for measuring the surface temperature. The temperature of each of these parts shall be measured three times every 30 minutes until equilibrium is reached. While measuring the temperature the thermometer shall be covered with a felt pad, asbestos or aluminium foil and kept in contact with that part for a sufficient period of time until the maximum temperature is reached.