

## Annex 1

### State Standard of the People's Republic of China Testing Method for the Heat Properties of Civil Firewood Stoves

The method is applicable for the heat properties testing of single-pot or multi-pot stoves fueled by firewood (firewood, crop stalks, tree leaves, etc.).

#### 1. Brief description of the method

The heat properties coefficient is determined through the temperature elevation and vaporization in a water boiling test by combusting firewood of given amount and quality to heat water of given amount in a pot.

#### 2. Heat properties coefficient

- 2.1 Heat efficiency refers to the ratio of total of the heat (over heat) absorbed by water in the pot during the process of temperature elevation and the heat (latent heat) absorbed by the water vaporized to the heat of firewood combusted in the stove. The ratio reflects the percent of heat utilized by the stove.
- 2.2 Temperature elevation rate - Elevation of temperature in a unit time. It reflects the starting performance of a stove.
- 2.3 Vaporization rate - The amount of water in the pot evaporated in a unit time. It reflects the starting performance of a stove.
- 2.4 Temperature regaining rate - Regaining of temperature of water in the pot. It shows a stove's performance on heat insulation and heat storage.

*Note: Total heat absorbed by all pots should be taken into calculation when determining the heat efficiency of a multi-pot stove (including stoves with heat recovery system). But only should the main pot be taken into account when determining temperature elevation rate, vaporization rate and temperature regaining rate of a multi-pot stove.*

#### 3. Instrumentation for testing

a thermometer with a measuring range of 0-100°C and graduated in 0.5°C.

a clock with error per day less than 2 minutes.

a platform scale with a measuring range of 0-10 kg and minimum sensing weight of 5 g.

a psychrometer

#### 4. Testing conditions

ambient temperature: 10-30°C

relative humidity: less than 85 percent

testing medium: water at normal atmospheric temperature

fuel used in the test: air-dried firewood

As a group of stoves are tested, the space between stoves should be larger than 1.5 m, and all stoves being tested should face the same direction.

#### 5. Testing procedure

- 5.1 The lower calorific value,  $Q_D^Y_w$  (kcal/kg) is determined.
- 5.2 There should be a port at the centre of the pot cover for installing the thermometer and, 6 exhaust ports evenly scattered concentrically at 1/2 radius of the pot cover. Total space of the ports is about 1 percent of that of the pot cover.
- 5.3 Volume of the pot  $G_G$  (kg) for containing water is determined.
- 5.4 The water  $G_{s_1}$  (kg), equivalent to 2/3 of  $G_G$ , is put into the pot.
- 5.5 The amount of firewood for testing is determined. Its weight should be 1/7-1/5 of the water weight  $G_{s_1}$  (kg) (depending on the lower calorific value of the fuel used).
- 5.6 The pot is covered with the pot cover. The thermometer is fit in the central port. The space between the thermometer bulb and the bottom of the pot is about 3 cm.
- 5.7 The beginning temperature of the water in pot  $t_1$  (°C), ambient temperature  $t_a$  (°C) and relative humidity (%) are measured and recorded.
- 5.8 Start to set the fire. The very time when the fire is set is recorded as  $T_1$  (hour : minute)
- 5.9 The very time  $T_2$  when the water in pot reaches the local boiling point  $t_2$  (°C) is recorded.
- 5.10 The fire is kept through continuously supplying firewood to heat the water to vaporize until the given firewood is used up.
- 5.11 The very time  $T_3$  (hour : minute) when the temperature of the water in pot deviates from the boiling point is closely noted and recorded.

- 5.12 The pot cover is quickly removed and the remaining water in the pot is removed and weighed  $G_{S_3}$  (kg). The water which has been prepared in advance at the weight of  $1/2G_{S_1}$  and at normal atmospheric temperature  $t'_3$  ( $^{\circ}\text{C}$ ) is put into the pot. Then the pot is covered again.
- 5.13 20 minutes later, the regaining temperature of the water in pot is recorded  $t'_4$  ( $^{\circ}\text{C}$ )
- 5.14 Clear the testing spot.
- 5.15 Repeat the test twice after the stove cools down to normal temperature.

**6. Calculation and process of testing results**

6.1 Fill in data form  
 During the process of the test, all data should be taken down in the data form (Table-1) at very time when they are obtained.

6.2 Formula for calculation

6.2.1 Temperature elevation rate

$$V_1 = \frac{t_2 - t_1}{T_2 - T_1} \text{ (}^{\circ}\text{C/min)} \dots\dots\dots (1)$$

in the formula

- $t_1$  --- beginning temperature of the water in pot ( $^{\circ}\text{C}$ )
- $t_2$  --- temperature at boiling point ( $^{\circ}\text{C}$ )
- $T_1$  --- the time when the fire in the stove is set (hour : minute)
- $T_2$  --- the time when temperature of the water in pot reaches the boiling point (hour : minute).

6.2.2 Vaporization rate

$$V_2 = \frac{G_{S_2} - G_{S_3}}{T_3 - T_2} \text{ (kg/minute)} \dots\dots\dots (2)$$

in the formula

- $G_{S_2}$  --- water weight when reaching boiling point (kg)
- $G_{S_3}$  --- water weight when deviating from boiling point (kg)
- Water weight  $G_{S_1}$  be taken as  $G_{S_2}$
- $T_3$  --- the time when water temperature in pot deviates from boiling point (hour : minute)

### 6.2.3 Temperature regaining rate

$$V_3 = \frac{t'_4 - t'_3}{T_4 - T_3} \quad (\text{°C/minute}) \dots\dots\dots (3)$$

in the formula

$t'_3$  --- beginning temperature of water in pot for regaining temperature test (°C)

$t'_4$  --- peak temperature of water in pot for regaining temperature (°C)

$T_4$  --- the time when the test ends and,  $T_4 - T_3 = 20$  minutes

### 6.2.4 Heat efficiency

$$= \frac{Gs_1 C_p (t_2 - t_1) + \tau (Gs_2 - Gs_3)}{G_c Q_D^Y W} \times 100 (\%) \dots\dots\dots (4)$$

in the formula

$C_p$  --- heat capacity of water at normal atmospheric pressure

$C_p$  may equals 1 kcal/kg

$\tau$  --- latent heat of vaporization at boiling point

$G_c$  --- firewood weight (kg)

$Q_D^Y W$  --- lower calorific value of firewood (kcal/kg)

$\tau$  values may be seen as below:

boiling point temperature, $t$ (°C)	86	88	90	92	94	96	98	100
latent heat of vaporization, $\tau$ (kcal/kg)	547.7	546.4	545.2	543.9	542.7	541.5	540.3	539.0

for multi-pot stoves, the formula is

$$\frac{\sum_{i=1}^n Gs_{1i} C_p (t_{2i} - t_{1i}) + \sum_{i=1}^n \tau (Gs_{2i} - Gs_{3i})}{G_c Q_D^Y W} \times 100 (\%) \dots\dots\dots (5)$$

in the formula

$Gs_{1i}$ ,  $t_{1i}$ ,  $t_{2i}$ ,  $Gs_{2i}$ ,  $Gs_{3i}$  --- corresponding value for pot  $i$ ;

$n$  --- total number of pots,

### 6.3 Data processing

#### 6.3.1 Calculation of coefficient

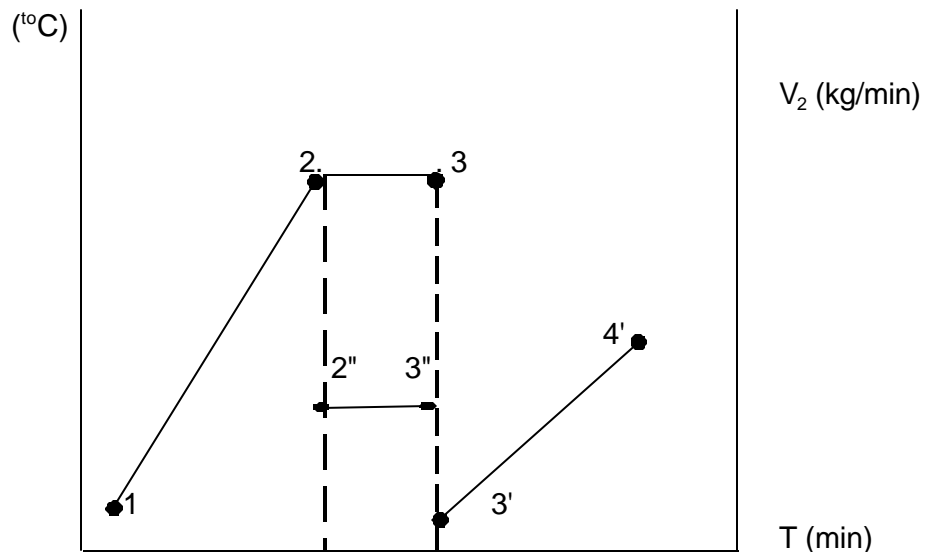
Each coefficient is calculated with the formulas and data obtained. In three calculations, arithmetic mean is taken,  $V_1, V_2, V_3$ , and comparison is made with corresponding coefficient value. The error should be within error allowance.

#### 6.3.2 Error allowance

The absolute value for absolute error of heat utilization efficiency should be less than or equal to 3.

#### 6.3.3 Describing curves

Testing results may also be expressed in form of curves as seen below.



#### Testing of stove for thermal characteristics

In above figure, the abscissa  $T$  represents time, the ordinate  $t$  refers to the temperature of the water in pot and  $V_2$  indicates the vaporization rate.

Line 1-2 shows the rate of temperature elevation. A steep slope of the line means a quick temperature elevation of water. Line 2'' - 3'' shows the performance vaporization. Long vertical section of the line indicates a strong vaporization during the test.

Line 3' - 4' shows the performance of heat insulation and heat storage of stoves. A steep slope of the line means the stove performs well in heat insulation and storage, i.e. high temperature regaining rate.

## 7. Test report

Title of stoves, type, producer, building materials, stove structure, testing conditions, testing results, date of test, place of test, operators, persons in charge, etc. should be noted in the report as shown in the data form below.

DATA RECORDING FORM	
name of stoves	.....
date	.....
time T (hour : minute)	.....
interval $\Delta T$ (minute)	.....
water temperature:	instantaneous $t_s$ ( $^{\circ}\text{C}$ ) .....
	difference in temperature $\Delta t_s$ ( $^{\circ}\text{C}$ ) .....
water weight:	at the beginning $G_{s_1}$ (kg) .....
	remain $G_{s_3}$ (kg) .....
	vaporized $\Delta G_s$ (kg) .....
weight of	
firewood $G_c$ (kg)	.....
low order calorific capacity $Q_D^Y$ (kcal/kg)	.....
Ambient temperature $t_a$ ( $^{\circ}\text{C}$ )	.....
relative humidity (%)	.....
	temperature elevation rate $v_1$ ( $^{\circ}\text{C}/\text{min}$ ) .....
results of	vaporization rate $v_2$ (kg/min) .....
calculation	temperature regaining rate $v_3$ ( $^{\circ}\text{C}/\text{min}$ ) .....
	heat utilization efficiency (%) .....
remarks:	
	tester.....

### Remarks:

This standard is put forward by Ministry of Agriculture, Animal Husbandry and Fishery.

This standard is within the responsibility of Chinese Academy of Agricultural Engineering Research and Planning. Chinese Academy of Agricultural Engineering Research and Planning is in charge of the drafting of the standard.

The standard is co-drafted by Cui Yuanbo and Chen Jing.

The standard is first issued in 1984.

## Annex 2

### Relationship between lower calorific value and the moisture content of biomass fuels often used in China

units: MJ/Kg.

Type	Moisture content								
	5	7	9	11	14	16	18	20	22
maize stalk	15.4	15.4	14.7	14.3	13.7	13.3	12.9	12.6	12.2
sorghum stalk	15.7	15.4	15.0	14.6	14.0	13.6	13.2	12.8	12.5
cotton stalk	15.9	15.6	15.2	14.8	14.2	13.8	13.4	13.0	12.6
beans straw	15.7	15.3	14.9	14.6	14.0	13.6	13.2	12.8	12.5
wheat straw	15.4	15.1	14.7	14.3	13.7	13.4	13.0	12.6	12.2
rice straw	14.2	13.8	13.6	13.1	12.6	12.3	11.9	11.5	11.3
millet straw	14.8	14.4	14.1	13.7	13.1	12.8	12.5	12.1	11.7
poplar branch	14.0	13.6	13.3	12.9	12.4	12.0	11.7	11.4	11.0
cattle manure	15.4	15.0	14.6	14.2	13.6	13.3	12.9	11.7	12.1
masson pine	18.4	17.9	17.5	17.1	16.4	15.9	15.5	15.1	14.6
birch wood	16.9	16.5	16.1	15.7	15.1	14.7	14.3	13.9	13.5