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Ben 2 and Ben 3 – Fuelwood Stoves
Contributing to Overcome the Firewood Crisis
General Description

See also:
http://solarcooking.org/Dieter_Seifert

Content:

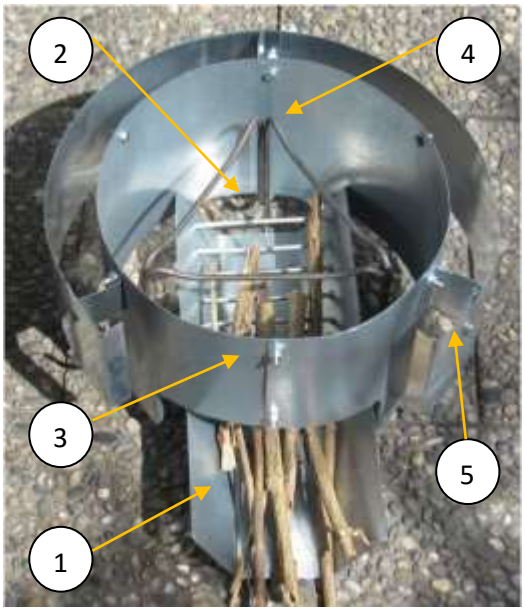

Fig. 1.1. Ben 2 with ash pan (1), grate (2), stove shell (3), tripod (4) and protecting shield (5)

Annexes A) … E)
see http://solarcooking.wikia.com/wiki/Ben_2_and_Ben_3_Firewood_Stoves

1. Objectives

The stoves Ben 2 and Ben 3 serve for cooking in pots up to 28 cm in diameter (Ben 2) or 28 cm to 32 cm in diameter (Ben 3). Pans and woks are also applicable. Dry, thin sticks of any length are used as fuel.

Ben 2 and Ben 3 are intended to be produced in small local workshops with locally available material (sheets, rods and strips made of mild steel), using simple tools, where required only with hand-held equipment[1]. For production in small series the presented devices (see Annexes) will be helpful.

The documentation can be used as open source. Of course, liability is excluded.

The thermal efficiency of the cooker is over 40% (see section 10). Compared to the traditional three-stone fire (with 10% efficiency), firewood consumption is reduced to less than a quarter (75% saving).

[1] See also: Some Remarks on Stove Technologies http://solarcooking.org/Dieter_Seifert

When thermos technique[2] is applied additionally, the firewood consumption drops to about one-seventh (see: Imma and Dieter Seifert: Notes on fireless cooking). This small amount of wood can be provided by plantations, which can be harvested annually.

If the use of charcoal from kilns is replaced, then the wood saving is even greater because multiples of wood is consumed for the traditional production of charcoal.

For overcoming the firewood crisis (see article "How to Overcome the Firewood Crisis" [3]) it is important on the one hand that the demand for wood is reduced to about one-seventh (demand in a week, which was formerly the daily requirement), that the remaining needs are covered by plantations, which may be harvested annually, and that the rebound effects are avoided. At the same time, the disease burden by carbon monoxide and nitrogen oxides is inhibited.

Fig. 1.2. Ben 2 with 28cm pot. Fuelwood sticks may be hold at cuts on the top edge of the ash pan.

2. Simplicity, high efficiency and durability

Construction of the stove is very simple. The stove consists of three parts which are placed into one another: ash pan with grate, stove shell and tripod for pots and pans with flat or curved bottom.

The operation of the stove is easy, both starting, as well as the maintenance of the fire on the firewood grate.

The stove weighs only about 4 kg; it is portable and can be produced with simple tools (optionally without any machine) of conventional mild steel. In the case of local production especially in developing countries the manufacturing costs are very low (in the order of 10 USD). Thus, the expense can often be paid back already in a month. Due to the low costs and high savings, the household may install more than one Ben stove (or several stove shells), suitable to the pots and pans used.

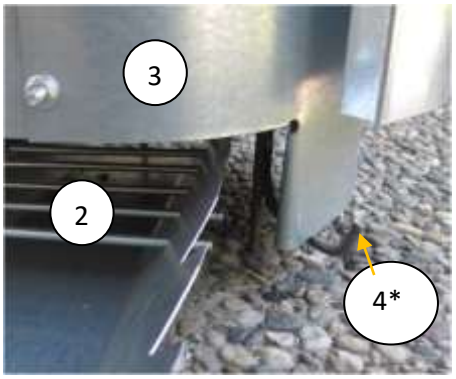

Fig. 1.3. Stove shell (3) supported on the extensions (4*) of the tripod legs (distance from bottom 3 cm) for the supply of the fire at the grate (2) with primary and secondary air.

Only little smoke is produced due to the effective supply of primary and secondary air. The thin steel sheets are not operated at high temperature so that they have a long lifetime.

Net thermal power of the stove is 1.5 kW. Six liters of water can be brought to a boil in less than 30 minutes. For this operation, about 0.4 kg of small, dry wood sticks are required.

With a daily consumption per household of 1.4 kg wood, the annual demand is about 500 kg, instead of usual 2000 kg to 4000 kg of firewood (or more than 7000 kg of wood if charcoal is used).

[2] http://vignette3.wikia.nocookie.net/solarcooking/images/4/4f/Notes_on_fireless_cooking_-_Seifert_2014.pdf/revision/latest?cb=20141208182323

[3] http://vignette3.wikia.nocookie.net/solarcooking/images/7/71/How_to_overcome_firewood_crisis-Dieter_Seifert-April_2015.pdf/revision/latest?cb=20150428221259

The efficiency is high due to the proper combustion and the advantageous heat transfer to the pot, caused by the special firewood grate and the adapted stove shell.

If solar technology is applied in addition (see e.g. the book of Imma Seifert: Solar Cooking with the Parabolic Cooker [4] - in 5 languages), then the demand for wood can be reduced to less than one kg per day per household, even if additional tasks are carried out with the solar cooker, e.g. boiling large quantities of water, baking breads and cakes, conserving fruits and vegetables. Thus the solar cooker is an effective means to avoid rebound effects.

3. Production of the stove

The stoves can be produced in very simple workshops with readily available material, even in school workshops. No machinery is required, but for preparing the holes of the steel sheets, an electric drill or a hand-operated punch will be helpful.

The stove consists of widely available standard material (mild steel, not stainless steel): steel sheets (e.g. thickness 0.75 mm) and round steel (e.g. diameter 6 mm).

Details about the production of Ben 2 and Ben 3 (including drawings, list of pieces and photos of the devices) are given in Annexes A) … E).

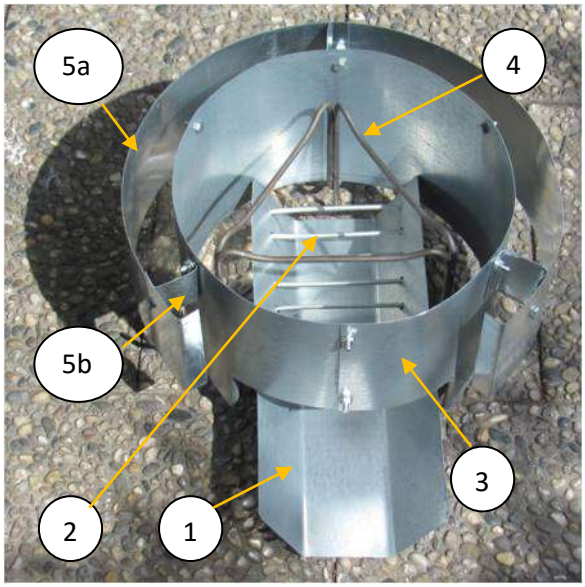

Fig. 1.4. Components of the stove (legend see chapter 4.)

4. Structure

The stove consists of three main parts, which are placed into each other (drawings and list of pieces see Annexes A) and E)):

a) Ash pan (1) with built-in grate (2)
b) Round stove shell (3) with protection shield (5a) attached with fasteners (5b)
c) Pot holder (4) in the form of a tripod for stable positioning of the pot resp. the pan.

The ash pan (1) is a thin, trough-shaped sheet of steel whose sides are provided with holes. Trough these holes the grate bars (2) are passed, on which the wood burns. To prevent that the bars will fall out, they are hairpin-shaped, so that they can be installed under tension.

The stove shell (3) consists of a round, thin sheet metal strip which is overlapped at the ends and bolted (or otherwise fixed). At the junction, the shell is cut in the circumferential direction on both sides to prepare a portal on the shell. The tabs are bent into the shell (after bending the shell round) to form a portal.

In Fig. 1.4. a shield (5a) is shown which is fixed on the stove shell (3) with fasteners (5b) to protect against burns if there is a danger.

[4] http://www.alsol.es/libro_cocina.pdf

Within the stove shell there is the pot holder (4) in form of a tripod[5]. The shown tripod is formed of round steel according the documentation in Annex E).

The stove shell is supported on extensions of the legs of the tripod so that the firewood on the grate is supplied from all sides with primary and secondary air.

The tripod is first set up, so that one leg is behind. Then the stove shell with the portal in front is put on the support on the legs of tripod. Finally the ash pan with the grate is installed through the portal until it reaches at the rear leg of the tripod.

Fig. 1.5. Ben 3 with stove shell (3) with 200 mm height for pot and (3*) with 150 mm height for pan or wok

5. Pots, pans and woks

The stove can be used for all usual cooking tasks, but not for baking (except for thin flat bread in a pan). The bottom of the pot can be planar or curved. The pot should be closed with a lid whenever possible.

The gap between the pot and the stove shell should be between 7 mm and 10 mm (see Fig. 1.2.) in order to achieve high efficiency. <u>If a pan or wok is used, it has to be ensured that there is a minimum distance of 5 mm between the pan and the top edge of the shell. If necessary, the stove shell is to be reduced accordingly.</u>

Fig. 1.5 shows on the left side a stove shell with 200 mm height which is intended for a pot. On the right side a stove shell with 150 mm height is shown to be used for pans and woks. The gap between the stove shell (3*) and the pan can be seen in Fig. 1.6.

Fig. 1.6. Ben 3 with stove shell (3*) with 150 mm height for pan/wok

6. Installation site

The stove should be operated in a place protected from wind and rain with good ventilation, e.g. walls on three sides, which have a free space to the roof so that the air can flow freely.

7. How to start and to maintain the fire

<u>The ash pan (1) must be emptied always before using the stove</u>, preferably into a tin can. For this purpose, the ash pan is pulled from the stove portal, emptied and installed backing against the rear foot of the tripod in the stove. The wood ash (and small pieces of generated charcoal) can be used as fertilizer. You can prepare a stiff paste from the ash with water, with which the outside of the pot can

[5] A tripod made of strip steel was described in the past (July 2015), but the new design (Annex E) with round steel has several advantages.

be coated, so that the soot can be easily washed off.

For lighting, two or three long (about 15 cm in length), thin rolls of newspaper are arranged on the grate so that they protrude with one end from the portal. On these rolls of paper, easily combustible small sticks are placed. If paper is not available, you can use the kindling alone.

Once the kindling is placed on the grate resp. the paper, the filled pot can be placed on the pot holder and then the fire is lit from the portal. Once the fire is strong enough, provided wood sticks are introduced through the portal. The sticks are pushed for getting enough fuel in the combustion area.

Experience teaches one very soon, how to deal with different sticks so that a lively, smoke free fire is maintained. It will also determine whether it is advantageous to support a part of the pieces of wood on the outer edge of the notched ash pan (see 1.7.).

Of course the small amount of dry sticks necessary for the whole operation has to be provided in the environment of the stove.

8. How to extinguish the fire

At the end of the active cooking process, before simmering in the thermos container, the pot is removed from the stove. To extinguish the fire, still burning sticks are pulled out of the portal and deleted on the long trough of the ash pan. For this purpose, it may be advantageous to use sand. Charred sticks are used for the next cooking process.

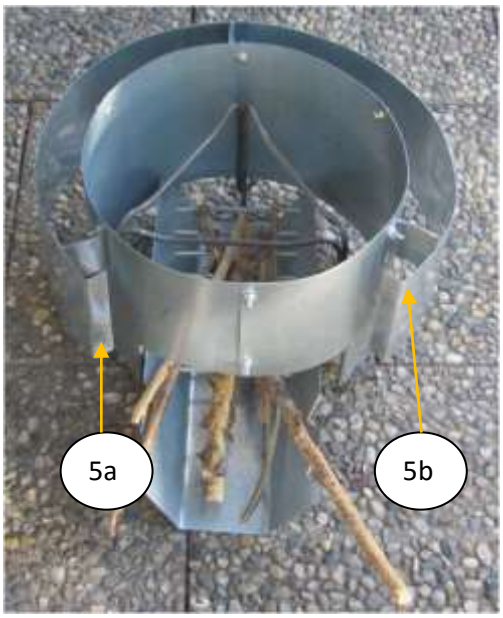

Fig. 1.7. Ben 3 with protection shield (5a), fixed on stove shell (3) with three fasteners (5b)

9. Safety precautions

<u>The conventional security measures for stoves have to be considered.</u> <u>The stove parts, with exception of the front part of the ash pan will get hot and must not be touched.</u>

The photo Fig. 1.7.shows a stove Ben 3 with a shield (5a) fixed on the stove shell (3), which may be appropriate if burns are to be feared.

The pot, the pan and the lid must be handled with potholders. Hot components of the stove are transported with pincers (Fig. 1.8.).

Fig. 1.8. Pincers are used for transport of the hot stove shell

Burning or glowing pieces should never come into contact with flammable substances.

<u>Never use any liquid combustible substances, neither during ignition nor during operation.</u>

If handled correctly, the stove is safe to operate. The pot (or pan) is stable placed in the stove. Within the long ash pan the burning wood is reliably protected against falling out. Fig. 1.8 shows an ash pan with a length of 400 mm. If desired, the ash pan can be extended with an additional trough.

10. Some Test Results

Table 1.1 contains test results with stoves Ben 2 and Ben 3 with pot (with lid) of 24 cm resp. 28 cm diameter. Calculated thermal efficiency η and effective thermal power P_{eff} are shown in the last rows.

		B1	B2	B3
	Type	**Ben 2**	**Ben 2**	**Ben 3**
Test Results Ben Stoves	Pot	24cm pot	24cm pot	28cm pot
	Fuel	wood	wood	wood
	Date	**03.02.2015**	**12.02.2015**	**04.02.2015**
Quantity of Water	kg	**6**	**6**	**6**
Start Temperature T1	**°C**	**12**	**12,8**	**12**
End Temperature T2	**°C**	**100**	**100**	**100**
Temperature Difference	K	88	87,2	88
Specific Heat of Water	kJ/kg/K	4,18	4,18	4,18
Energy for Heat Up of Water	kJ	2.207	2.187	2.207
Quantity of Vaporated Water	**kg**	**0,050**	**0,152**	**0,070**
Specific Heat of Vaporization	kJ/kg	2.260	2.260	2.260
Heat of Vaporization	kJ	113	344	158
Effective Energy E_eff	kJ	2.320	2.530	2.365
Quantity of Supplied Fuel	**g**	**411**	**390**	**417**
	kg	0,411	0,390	0,417
NCV_wood (15% humidity)	kJ/kg	15.000	15.000	15.000
Supplied Energy E_in	kJ	6.165	5.850	6.255
Quantity of Remaining Charcoal After Extinguishing the Fire	**g**	15	0	15
NCV_charcoal	kJ/kg	30.000	30.000	30.000
Residual Energy E_res	kJ	450	0	450
Consumed Energy E_consumed	kJ	5715	5850	5805
Thermal Efficiency eta	%	**40,6%**	**43,3%**	**40,7%**
Heat Up Time t	minute	24,00	30,00	26,00
	s	1440	1800	1560
Effective Power P_eff	**kW**	**1,61**	**1,41**	**1,52**
Firepower Q_fire	kW	3,97	3,25	3,72

Table 1.1. Examples of test results with Ben 2 (columns B1 and B2) and Ben 3 (column B3)

11. Savings and other benefits by connecting with thermos technology and solar cookers

With an efficiency of 40%, one can reduce the need for firewood on a quarter of the consumption of a traditional open fire (three rock stove with 10% efficiency default value). Applying additionally the thermos technology (e.g. with a hay basket or wonderbag) the firewood consumption is reduced to one-seventh. Then only few sticks are needed that grow every year (e.g. pigeon peas). Thus, there remains only very small fuel consumption, no cumbersome search, no heavy loads, no destruction of trees with all the negative consequences for humans and nature.

With the solar cooker a further reduction of the consumption to one-tenth or one-twelfth of the traditional consumption is possible. The solar cooker can be used for additional tasks, as baking and preserving fruits or vegetables, which are hardly possible with the stove.

This combination of technologies and their advantages corresponds to the “Integral Cooking Method”[6] and may extend it. The paper[7] “How to Overcome the Firewood Crisis” contains additional proposals.

[6] http://solarcooking.wikia.com/wiki/Integrated_Cooking_Method
[7] http://solarcooking.org/Dieter_Seifert

12. A Quotation

from a contribution of Dr. Sena Gabianu: "AFRICA'S GROWING AWARENESS OF PROBLEMS OF ECOLOGY AND ITS LINKS TO SOCIAL AND ECONOMIC DEVELOPMENT" at a seminar held at Neuendettelsau (Germany) in May 1996, which may still be of actuality:

"There is a project running in Ethiopia right now being extended by ILO to help the Women Fuel Wood Carriers. This is a very special group of women, very poor, who can be seen carrying loads of wood on their backs from far off forests to sell in the cities. … They are really the poorest of the poor. But as they told us, they do not need to beg on the streets. The project is helping them to get a sense of self adequacy and dignity. They are to be helped with a micro-credit scheme to get other skills. They know they are being blamed for unauthorized cutting down the forest, destruction the young trees and even the collection of leaves which in the past fell by themselves and regenerate the land, but they don't know else to live. … There is promise in Solar Energy but as one lady told us at a seminar, she has heard so much about solar energy and how abundant the sun is, yet she has to look up to the skies every day, watch the sun go from east to west, shedding a lot of its energy and there is no way she can bring it down to do her cooking with. May be, she added, those of you who have education can help us."

Source: O. Ischebeck (ed.): FROM FOSSIL FIRE TO THE SUN – Renewable Energies for Sustainable Development and Employment in Africa, Akademischer Verlag München, 1997, p. 18-19.

Anexes[8]

Annex A) Drawings of Fuelwood Stoves Ben 2 and Ben 3 with List of Parts
Annex B) Description of Devices (D1) … (D3), (D7) … (D10) for serial production of ash pan, grate, stove shell and protecting shield
Annex C) Drawings of Devices (D1) … (D3), (D7) … (D10) with List of Parts
Annex D) Photos of Devices
Annex E) Documentation for production of tripod (4W) of round steel.

[8] See http://solarcooking.wikia.com/wiki/Ben_2_and_Ben_3_Firewood_Stoves