The **Lean Water Boiling Test (WBT)**

The internationally recognized test protocol for cooking devices is the Water Boiling Test (WBT) according to ISO 19867. Since the full test protocol can only be performed in sophisticated laboratories, the **lean** Water Boiling Test was compiled for small stove builders and briquette makers. It is valid for any stove, even for gasifiers and 3-stones fires.

Nomenclature

t	Time (in seconds)
T	Temperature (in K or °C)
T_1	Initial temperature
T_2, T_3 ...	Final or intermediate temperature(s)
T_{wo}	Ambient temperature
c	Specific heat capacity (in kJ/kg)
c_{wa}	Specific heat capacity of water (4.186)
c_{Al}	Specific heat capacity of aluminum (0.897)
c_{Fe}	Specific heat capacity of iron (0.444)
ΔT	Temperature difference
T_{LBP}	Local boiling point (95° on Lake Victoria)

What you need

- A wind-safe location
- 5 kg of water
- Quick response thermometer or thermocouple
- Pot for boiling purposes
- Stove
- Scale
- Solid fuel (wood, briquettes), max. 20% moisture content
- Kindling material
- Matches or lighter
- Dry sand

Test procedure, cold start phase

1. Note down the ambient temperature and the initial temperature of water.
2. Weigh the kindling material **and** the fuel wood, then note it down.
3. Weigh the pot, note down the weight and the material of the pot.
4. Start the fire.
5. Put the pot with 5 kg water on the stove.
6. Note down the temperature of the water in previously determined intervals, e.g. every three minutes or every 5 minutes.
7. Continue with temperature notation until the water reaches 95°C which is the T_{LBP} at lake Victoria locations.
8. Take the pot off the stove.
9. Put embers and unburnt solid fuel on the ground and cover them with the dry sand.

After a while:

10. Separate the sand from the left over coal and unburnt fuel. Weigh the unburnt material and subtract the weight from the initial fuel weight (see step 2.). The result is the actually used fuelwood weight.

The previously described steps determine the module *cold start phase*.

Extension module **Simmering Phase**

The module Cold Start Phase describes the heat transfer efficiency. For the determination of the behavior of the fuel and the heat transfer in the Simmering Phase please continue the notation at step 8 of the Cold Start Phase until the water temperature comes down to 6° below T_{LBP}. Do not add further wood/briquettes during the simmering phase; just use the embers in the stove.

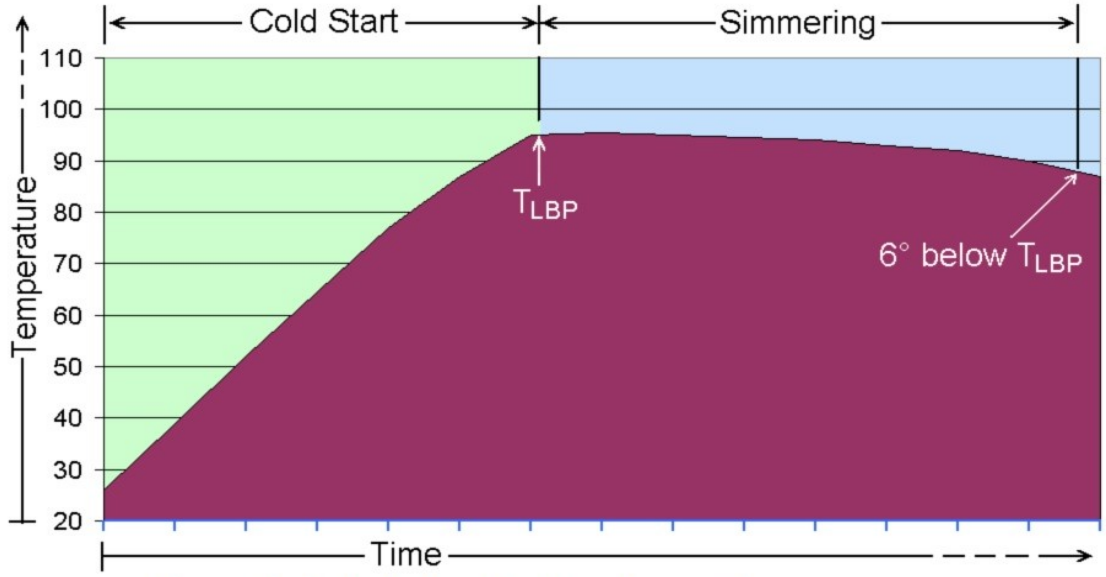
Water loss due to vaporization

The water loss is gained energy, as part of the cooking energy has been diverted to vaporization. The c_p of water vaporization is 2270 kJ/kg.

Example formula how to determine the energy gain by water vaporization if you lost 60 grams of water during the water boiling test: 0.06 * 2270 = 136.2 kJ. This is a rough figure since the vaporization depends also a little on temperature and pressure, but it comes near to a useful estimate. If you are not working on a scientific level, you are free to skip this vaporization paragraph.

Conversions

One J (Joule) is one Watt-Second. 3,600 J = 1 Wh. 3,600,000 J = 1 kWh.
One kJ (KiloJoule) = 0.239 kcal, 1 kcal = 4.184 kJ (the c_p of water).
T_{LBP} = Reduce by 1°C per 300 m altitude, roughly. Hence, the T_{LBP} for the lake Victoria area has been determined at around 95°C. T_{LBP} at sea level: 100°C.



Above chart illustrates the time-temperature progress

Photo on 1st page shot by Esther Nattabi, 2020. It shows a double-walled clean cookstove “Baba Moto Blue”, designed by Ssembatya Mohammad, of UGwal Clean Energy Ltd., Kampala, Uganda.

WBT – Lean Version, cold start phase	v. 1.0.0

Results are displayed in red letters

5,0 kg water to be boiled	Initial water temperature 25,9°C	Ambient temperature 27,7°C

Stove model and manufacturer: Single walled AfroBasic, Version Awamu, UGwal (Uganda), Omolo (Kenya)

Location where the test has been conducted Place and country: Kampala, Uganda	Altitude	Coordinates Latitude	 Longitude	Date tt.mm.jjjj
	1155m	0°	32°E	24.06.2019
Local boiling point at this location is	**96°C**			

Initial fuel	0,6392 kg	Fuel consumption		kJ del.	Evaporated
Kindling material	0,01 kg	/w Kindling mat.	**0,4897 kg**	**7345,5**	0,0889 kg
Unused fuel	0,1496 kg	w/o Kindling	0,4887 kg		**228 kJ**

Local time	Elapsed time (hh:mm)	Temperature °C	kJ
14:50	00:00	25,9	
14:52	00:02	31	0,94
14:54	00:04	37	0,97
14:56	00:06	44	1,24
14:58	00:08	51	1,29
15:00	00:10	56	0,96
15:02	00:12	62	1,06
15:04	00:14	69	1,24
15:06	00:16	77	1,26
15:08	00:18	83	1,06
15:10	00:20	87	0,78
15:12	00:22	92	0,88
15:14	00:24	95,6	0,60

Weight of pot and lid
0,341 kg

Material and specific heat capacity of the pot

x	Aluminum	0,897 kJ/kg
	Iron	

Average	**1,02**	kJ	
multiplied by 1476 seconds	**1511**	kJ	
Evaporation enthalpy	**228**	kJ	
Energy, total	**1739**	kJ	
Heat transfer efficiency	**23,68**	%	
Specific fuel use per liter water	**0,098**	kg	(efficient 3-stones fire: 0,260 kg)

Compared to an efficient 3-stones fire, this stove saves 62,3% fuel wood.