

Stove Emissions and Efficiency Testing Laboratory Ulaanbaatar, Mongolia

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STOVE TEST REPORT

Test Number 081 Date 2010-08-22 Test requested by: ADB

1. PRODUCT DESCRIPTION

Stove Name Traditional Stove manufacturer Street Stove provided by ADB

Notes about stove: This is a traditional stove in good condition operated in a traditional manner with coal having been dried through the summer in the laboratory. It is a quick investigation to see if the PM and CO are affected by the drying of the fuel alone with no other changes in technique.

Combustion type Bottom-lit updraft Intended application for the stove Heating/cooking
(updraft/ cross draft/ downdraft/ gasifier) (heating/cooking/low pressure boiler/wall stove)

Fuels specified for use in this product Nalaikh raw coal broken to about 25/35 mm

Lighting method suggested by the manufacturer:

A wood fire is lit at the front and some coal placed upon it when it is burning well. When that coal is lit, more is added. It is the standard operating technique for traditional stoves.

2. FUEL DESCRIPTION

2.1. Name Nalaikh raw coal

2.2. Source On the street

2.3. Analysis performed by C Pemberton-Pigott

2.4. Heating Value: Lower Heating Value (LHV) 17.12 MJ/kg and As Received 16.55 MJ/kg

Analysis As Received (AR)

Moisture % As Received (AR)	20.70	% WWB
Ash %	6.34	% Wet Basis
Sulphur %	0.46	% Wet Basis, Ash in
Hydrogen %	4.19	% Wet Basis, Ash in
Carbon %	56.30	% Wet Basis, Ash in
Oxygen %	10.75	% Wet Basis, Ash in
Nitrogen %	1.25	% Wet Basis, Ash in

3. PHOTOGRAPHS OF THE BASELINE STOVE



Typical traditional Mongolian cooking and heating stove with a sheet metal top.

4. TEST DESCRIPTION

Stove operated by Tseyen-Oidov Data recorded by Crispin+Lodoysamba+ Oidov

Test Protocol used Standard, without refuelling Starting time 11:00 AM Ending time 14:27 PM

Lighting procedure used As above

Notes about the environment during the test :

PM 2.5 about 45 microgrammes per cubic metre in the laboratory air, a typical summer level.

5. TEST RESULTS, SUMMARY

5.1. Data analysis sheet version number used 2.59.4

5.2. Summary results

5.2.1. Fuel loaded during first burn, g 3,800

5.2.2. Burn time, minutes 73

5.2.3. Fuel loaded during refuelling, g 2378

5.2.4. Refuelling burn time (minutes) 125

5.2.5. Percentage of fuel burned when analysis of the test ended 90%

5.2.6. kW (average) during whole burn 5.38 kW

5.2.7. PM2.5 per Net MegaJoule of heat produced 794.28 milligrammes

5.2.8. CO emitted per Net MegaJoule of heat produced 16.61 grams

5.2.9. Notes about summary results:

This is a typical burn cycle for a medium-sized ger stove. The power level ramped rapidly and the coal mostly burned out in just over an hour. There is a very high peak power followed by a rapid collapse.

5.2.10. Notes about the operation of the stove during the test:

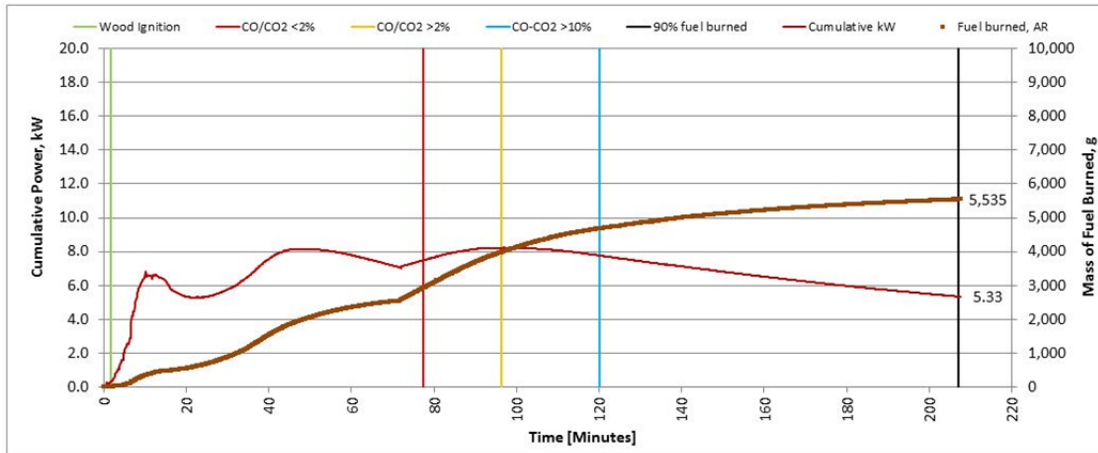
Nothing special.

6. DETAILED RESULTS AND CHARTS

6.1. POWER and FUEL CONSUMPTION

Stove Manufacturer: Ulaanbaatar	Test date: 22/Aug/2010
Stove Model: Traditional stove, traditional fire	Type of Fuel: Nalaikh Nov '10

Cumulative Kilowatts and Mass of Fuel Burned 081.10.2.1 Traditional stove, traditional fire 22/08/2010 Test No. 081

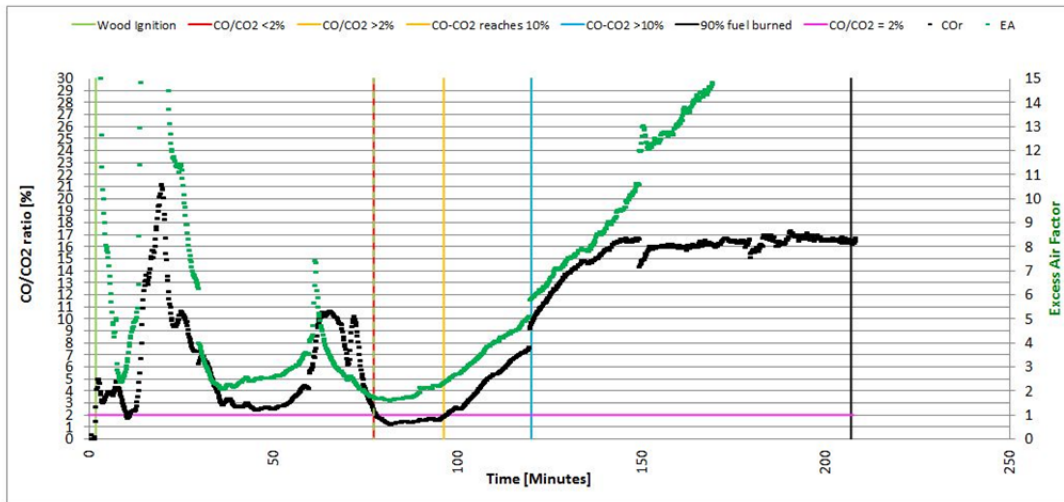


Traditional stove, traditional fire

The fluctuating power level is clearly shown by the varying change in the mass burned per minute. When refuelled it has the same slope (brown line) as when first fired indicating consistent behaviour.

6.2. COMBUSTION EFFICIENCY AND GAS EMISSIONS

CO/CO2 Ratio and Excess Air 081.10.2.3 Traditional stove, traditional fire 22/08/2010 Test No. 081

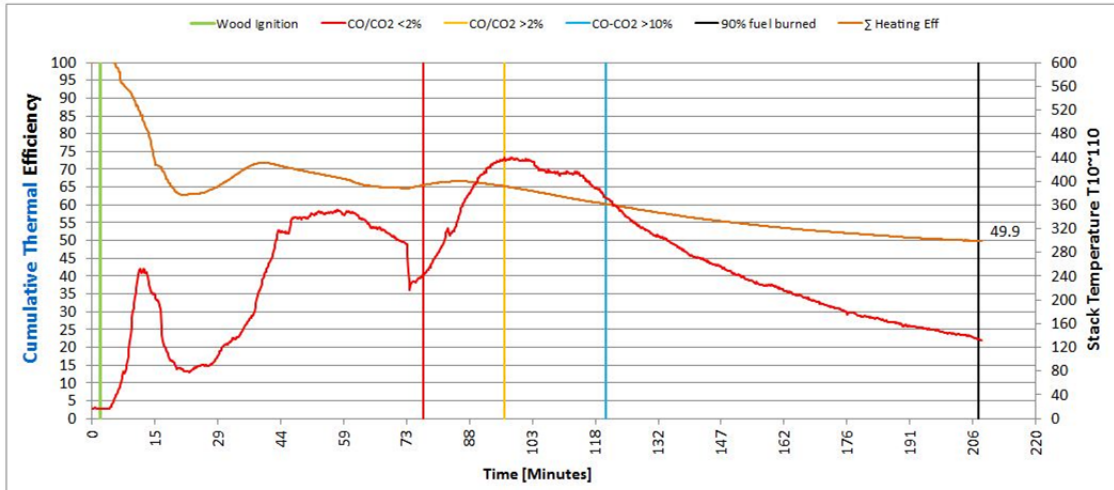


Traditional stove, traditional fire

Only when the stove was refuelled did the CO/CO2 ratio drop below 2%.

6.3. THERMAL EFFICIENCY OF HEATING AND COOKING

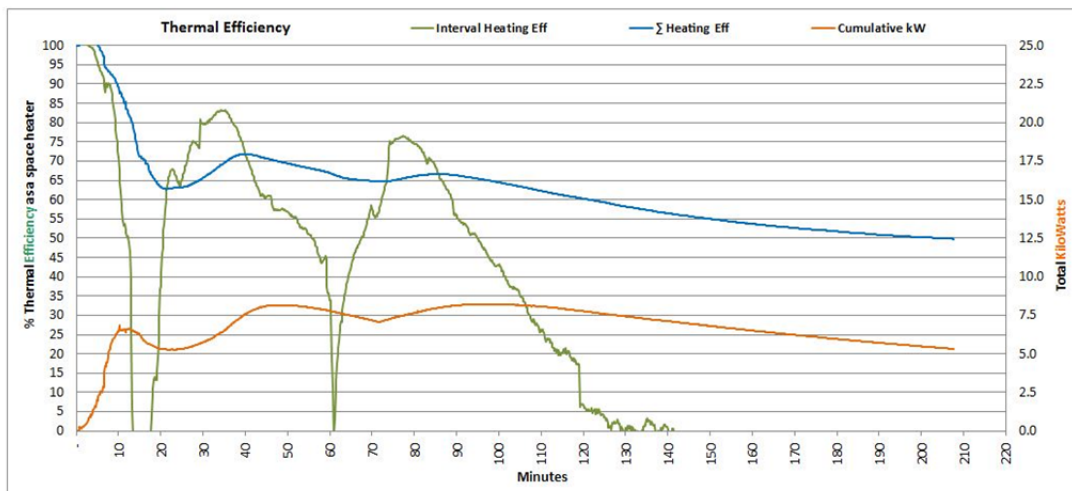
Flue Temperature & Thermal Eff. as a Heater 081.10.3.1 Traditional stove, traditional fire 22/08/2010 Test No. 081



Traditional stove, traditional fire

The thermal efficiency is about 70% on high power but rapidly drops as the fire dies down.

Thermal Efficiency (space heating) and KiloWatts 10.3.4 Traditional stove, traditional fire 22/08/2010 Test No. 081



Traditional stove, traditional fire

The huge drop in thermal efficiency when the fire is not large is the reason for the low overall average. In fact when the fire is small, it cools the home by pulling in cold air and sending hot air up the chimney. The instantaneous efficiency (green) fluctuates more than 300% from +80 to -250%.

6.4. PARTICULATE EMISSIONS

Stove Manufacturer: Ulaanbaatar
Stove Model: Traditional stove, traditional fire

Analysis Sheet v. 2.594

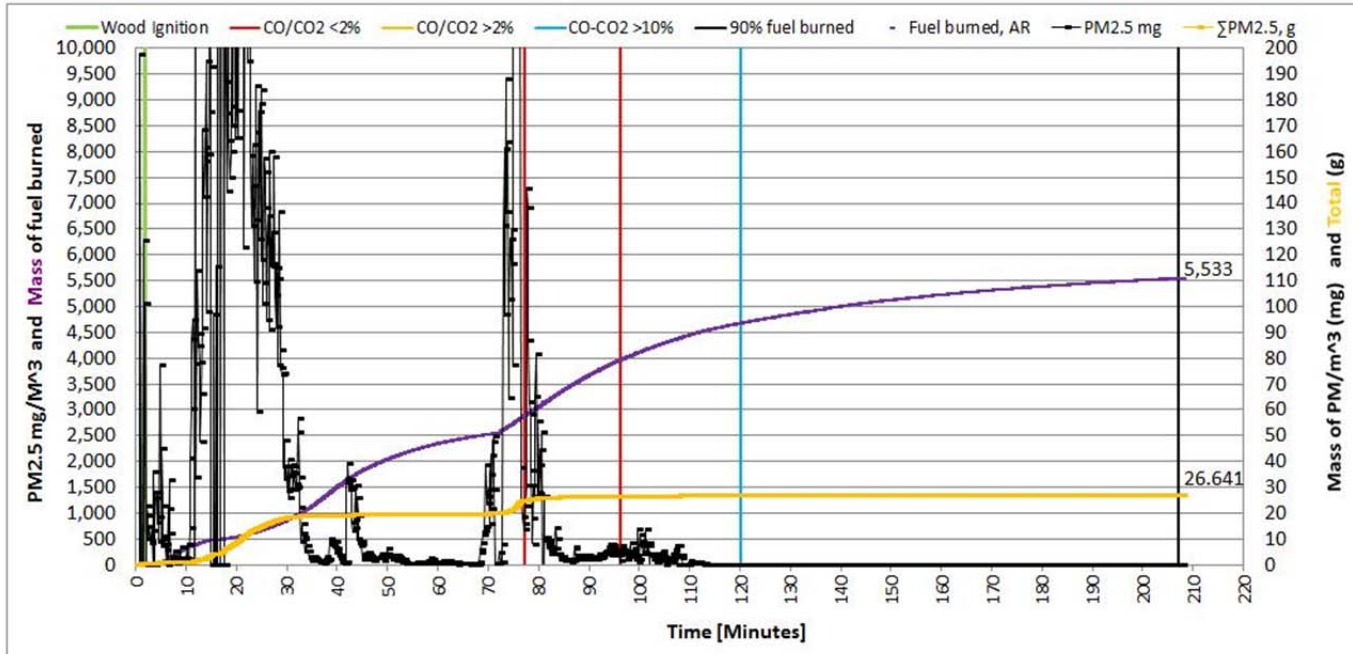
Test date 22/Aug/2010
Type of Fuel Nalaikh Nov '10

PM 2.5 and Mass Burned 081.10.4.1

Traditional stove, traditional fire

22/08/2010

Test No. 081



Note:
The ash is still in the stove.
The heat value/kg considers this.
The test should end when 90 % of the fuel loaded (total) has been burned.

	PM	CO
Traditional stove baselin	650	13.5
Reduction by this stove	-22.20%	-23%

Emissions created to deliver heat into the home

Emissions per Net MegaJoule	
PM2.5	794.28 mg per Net MJ in the home
CO	16.61 g per Net MJ in the home

Combustion only, stove efficiency not considered

PM2.5	395.90 mg per MJ
CO	8.28 g per MJ

Traditional stove, traditional fire

The ignition emissions from the wood are fairly high, but not nearly as bad as the coal once it gets going. As there is no way to burn the gases produced by heating the coal from underneath, a great deal passes up the chimney. The refuelling emissions are quite high as well but because the stove is hot, the fire tends to burn better, earlier.

6.5. PERFORMANCE

SEET Laboratory Test Single Test Analysis 081.10.5.3 Test No. 081 Analysis Sheet: v. 2.594
 Stove Manufacturer: Ulaanbaatar Stove Model: Traditional stove, traditional fire

Traditional stove, traditional fire Report		Date	Time	Fuel	LHV, MJ/kg	Analysed by		
Enter line numbers in Column C to divide the test into relevant sections. The last line is auto-set on Test Info page		22/08/2010	10:50 AM	Coal	12.0			
Event Occurs on Line Number:	Stove Power per section Watts	0	0	Average CO/CO2 ratio	CO ₂ Emitted /kg burned	CO Emitted /kg burned	CO emitted during this portion, g	H ₂ O Delta T during this section
16	7,652	0.0%	0.0%	6.2%	1,812	66	192.2	#REF!
469	Minutes of burn	75.52	VALID	This cooking section can overlap other sections				
469	CO/CO2 <2%	11,219	0.0%	1.5%	1,895	17	18.5	#REF!
583	CO-CO2 reaches 2%	Minutes of burn	19.02	VALID				
583	CO/CO2 >2%	5,911	0.0%	5.0%	1,832	55	38.4	#REF!
728	CO-CO2 reaches 10%	Minutes of burn	23.75	VALID				
728	CO-CO2 >10%	1,977	0.0%	15.7%	1,664	154	132.4	#REF!
1,249	90% fuel burned	Minutes of burn	86.90	VALID				
Initial Mass of Water Boiled, g	-	Adjusted to 80 deg	COOKING	Whole Test				
Time to Boil, minutes (Green section above)	75.52	#REF!	#REF! minutes/Litre	Beginning line	16			
Ash-corrected Fuel to Boil, g (Green section above)	2,896.22	#REF!	#REF! g/minute	Ending line	1,249			
Sp Fuel Consumption to boil, g/litre	#DIV/0!	#REF!	#REF! g/minute/litre	Fuel burned, g	5,529.9			
Energy to boil 1 litre, MJ	#DIV/0!	#REF!	#REF! Eff, adjusted for temperature	Minutes of test	205.2			
CO emitted to boil 1 litre, g	#DIV/0!	#REF!		Avg g/minute	26.95			
				Max/Min ratio	5.68			
Stage	CO, g Per hour	CO/CO ₂	CO, g/Net MJ	PM2.5 mg/net MJ	CO, g/MJ	CO g/kg AR	CO ₂ g/MJ	CO ₂ g/kg AR
CO-CO2 reaches 2%	152.7	6.20%	8.47	1,078.43	5.54	66.37	151	1812
CO/CO2 <2%	58.4	1.55%	2.25	173.77	1.45	17.33	158	1895
CO/CO2 >2%	97.0	5.04%	14.22	113.45	4.56	54.56	153	1832
CO-CO2 >10%	91.4	15.65%	208.29	0.67	12.85	153.85	139	1664
Whole Test	160.3	9.55%	16.61	794.28	8.28	99.14	147	1756
Stage	PM 1.0 g	PM 2.5 g	PM 4.0 g	PM 10 g	PM2.5 mg/MJ	PM2.5 g/kg AR	PM10 mg/MJ	PM10 g/kg AR
CO-CO2 reaches 2%	24.455	24.472	24.472	24.472	705.785	8.450	705.796	8.450
CO/CO2 <2%	1.431	1.432	1.433	1.433	111.905	1.340	111.912	1.340
CO/CO2 >2%	0.306	0.306	0.306	0.306	36.354	0.435	36.359	0.435
CO-CO2 >10%	0.001	0.000	0.000	0.000	0.041	0.000	0.038	0.000
Whole Test	26.191	26.210	26.211	26.211	395.901	4.740	395.910	4.740
Stage	MJ Yielded	Fuel, kg/hr AR	Thermal Eff	Heat, kW	Net heat, kW	Time, Hrs	Net KWHours	Cooking Eff
CO-CO2 reaches 2%	34.67	2.30	65.4	7.65	5.01	1.26	6.30	-
CO/CO2 <2%	12.80	3.37	64.4	11.22	7.22	0.32	2.29	-
CO/CO2 >2%	8.42	1.78	32.0	5.91	1.89	0.40	0.75	-
CO-CO2 >10%	10.31	0.59	-6.2	1.98	-0.12	1.45	0.18	-
Whole Test	66.20	1.62	49.8	5.38	2.68	3.42	9.17	-

Colour Coding
Combustion efficiency
MJ related
Mass related
Section 1
Section 2
Section 3
Section 4
Whole test

Beginning line
 Ending line
 Fuel burned is ash-corrected
 3.42 Hours
 g/minute is ash corrected
 Includes all 4 test sections

Notes:
 Net Heat is the same as the electrical heat needed for the same amount of heat to be delivered into the home.
 Totals ignore section overlaps and underlaps

Eff is mass compensated

6.6 TEST INFORMATION

Test Information

Stove Emissions and Efficiency Testing
Laboratory

This spreadsheet is v. 2.594

General

Save as sheet 081.10.5.1

Physical location where the test was conducted	STEL Ulaanbaatar
Test Number	081
Test date	22 August 2010
Test Time	10:50:00
Pot On	
Test Administrator	C Pemberton-Pigott
Test Name	Traditional stove with refuelling episode using Front Lighting Cross Draft method
Test Analysis performed by	

Testing Environment

Ambient Temp in the testing room	17	°C
Oxygen %	0.21	%
CO, %	0.04%	%
CO ppm	1 ppm	ppm
Relative Humidity	Unknown. Low	%
Stack Rel. Humidity	Unknown	%
Ambient PM 2.5 reading at the start of testing	45	µg/m ³
Ambient PM 2.5 reading at the end of testing	45	µg/m ³

Stove Description

Stove Manufacturer:	Ulaanbaatar	
Stove Model:	Traditional stove, traditional fire	
Stove Type (Cooking, Space Heating etc...)	Space heating and cooking	
Chimney (Yes/No)	Yes	
Description	10 kW Traditional stove, coal and wood, front lighting	
Dimensions, L, W, H		mm
Vertical height from base to the flat top surface	480	mm

Chimney Description

Description	Three part chimney with a diluter attachment at the bottom.	
Total vertical height	3.43	Metres
Total length of the gas path	Inside stove 0.93, total chimney 3.43, total 4.36 M	Metres
Length from stove to the roofline: T~2	Floor to roofline sample point (Temp 2) 1.5 from the 'floor' (T2)	Metres
Length from roofline to top	1.0	Metres
Diameter, mm	90	mm

Fuel

Save as sheet 081.10.5.2

Type of Fuel	Nalaikh Nov '10	
Average moisture content	26.10	%
As Received (AR) heat content of fuel	11.97	MJ/kg
Average diameter mm	25	mm
Average length mm	25	mm
Fuel added during the initial burn, g	3800	g
Fuel added during refuelling, g	2378	g
Percentage of fuel that should be burned during the test	90	%
Char Remaining at the end (wood fires)	0	g
Total Fuel Added	6178	g
Maximum burnable/evaporable mass (ash only remaining)	5813	g
Test ended when this much of the fuel was burned (%)	90.1	%
Test ends when this total mass is missing from the scale	5231	g

Cooking Performance Test

Pot used: Maker	
Name given in the Laboratory	
Diameter	
Depth	
Capacity	0.00
Pot Mass, empty without lid	
Lid mass	
Pot plus Lid plus Water, at the beginning of the test	
Pot1, Mass with lid	0
Water Mass	0

Correction factor for the Particle measurements

1.000

6.7 WATER BOILING

7. DISCUSSION

- 7.1. The test shows that the traditional Mongolian coal stove lights relatively easily but uses rather a lot of wood doing so. Enough wood must be used so that then the coal is placed on top of it, it continues to burn. The heat output is large initially then dies away rapidly giving a typical too-hot then too-cold cycle.
- 7.2. The PM is largely produced during the ignition process as well as the refuelling that takes place later when the stove is hot. The hot stove develops a good fire sooner than when the stove is cold. In both cases the smoke of smoke is prodigious. The excess air ratio is too high which leads to large losses of heat when the fire is small and the generation of a great deal of CO. CO is partially burned carbon and represents a significant additional loss.
- 7.3. The stove appears to be well made. It is a new stove and was run expertly. It is assumed that the emissions will be higher if it is not operated as well. It can be produced in large numbers and this is the dominant stove type found in the ger communities.
- 7.4. The cooking ability was not tested at this time. Earlier tests indicated the cooking efficiency is about 15%. This is low and is typical of a well-managed open fire. The cooking power is very high after about 40 minutes which is appreciated by the cooks in Mongolia. The pot sits properly into the hole provided. There are no rings to suit smaller pots.
- 7.5. It is expected to save about 30% of the fuel normally used.
- 7.6. The traditional stove is the baseline so it constitutes the emissions against which other stoves will be compared.
- 7.7. The average power during the test period was 5.38 kW. With the thermal efficiency factored in, it delivers 2.68 kW into the home. There is a small heat exchanger on the back of the stove which is too small to effectively pass heat into the home. As a result the chimney temperature is often very high.
- 7.8. There should be no durability issues with the steel components because the interior of the stove is lined with bricks and clay. A typical life is 5 to 10 years.