The Water Boiling Test (WBT)

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Why?


"Speculation is worthless"
Damon Ogle
40
60
80
20
0
-20
-40
120
140
SONY

Laboratory Comparisons

End Goal

Work

?

Reward

Method

Truth

~

Approximation

Major Measurables

Water Temperature

Water Weight

Wood Weight

Charcoal Weight

Other Measurables

Wood Moisture Content

Air Temperature

Controlled Quantities

Boiling Temperature

Fuel Type

Documented Data

Fuel Dimensions

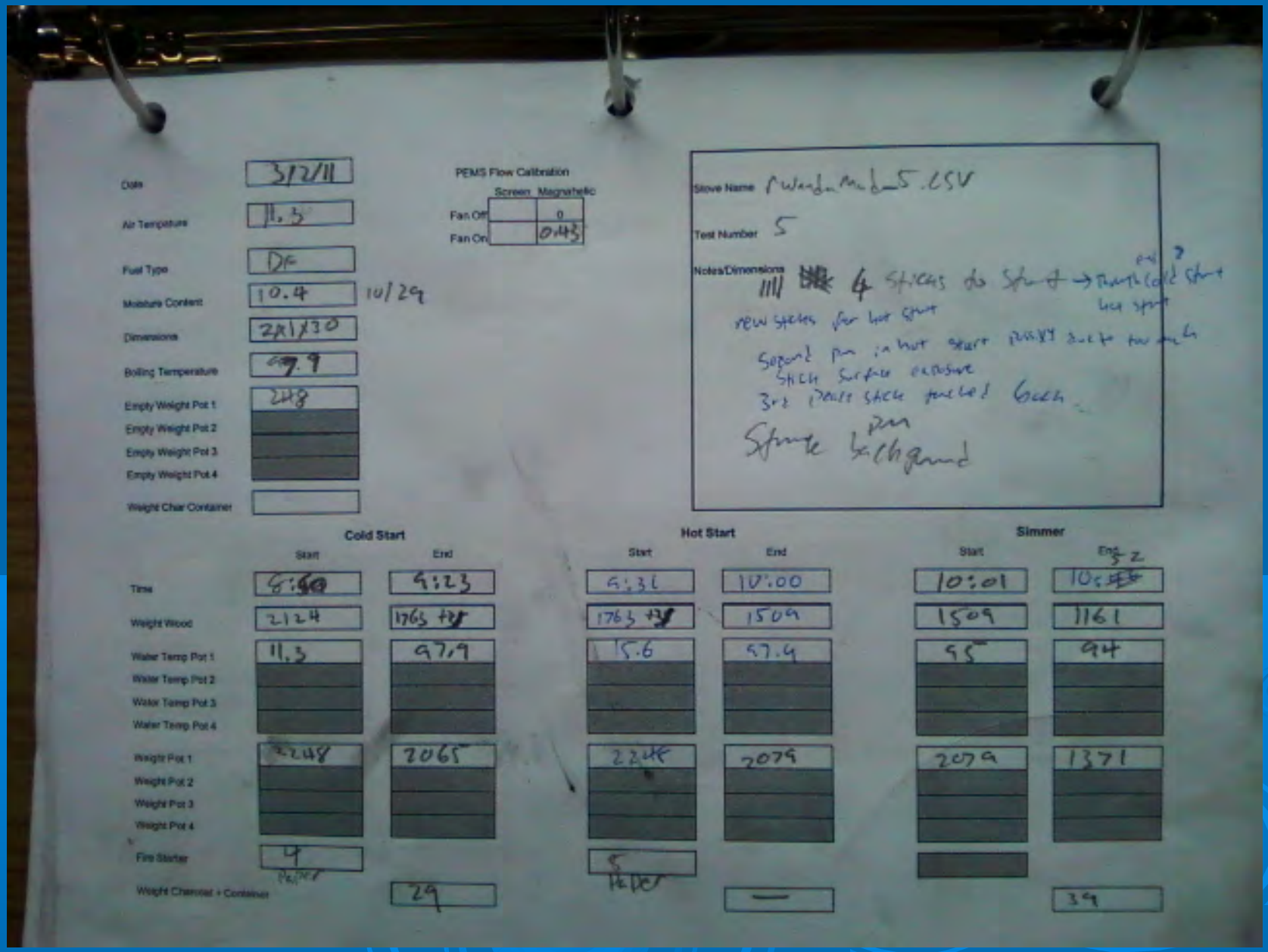
Fire Starter

Uncontrolled Quantities

Number of Sticks

Orientation of Sticks

Data Collection



Date: 3/2/11
Air Temperature: 11.3
Fuel Type: DF
Moisture Content: 10.4 10/29
Dimensions: 2x1x30
Boiling Temperature: 97.9
Empty Weight Pot 1: 248
Empty Weight Pot 2
Empty Weight Pot 3
Empty Weight Pot 4
Weight Char Container

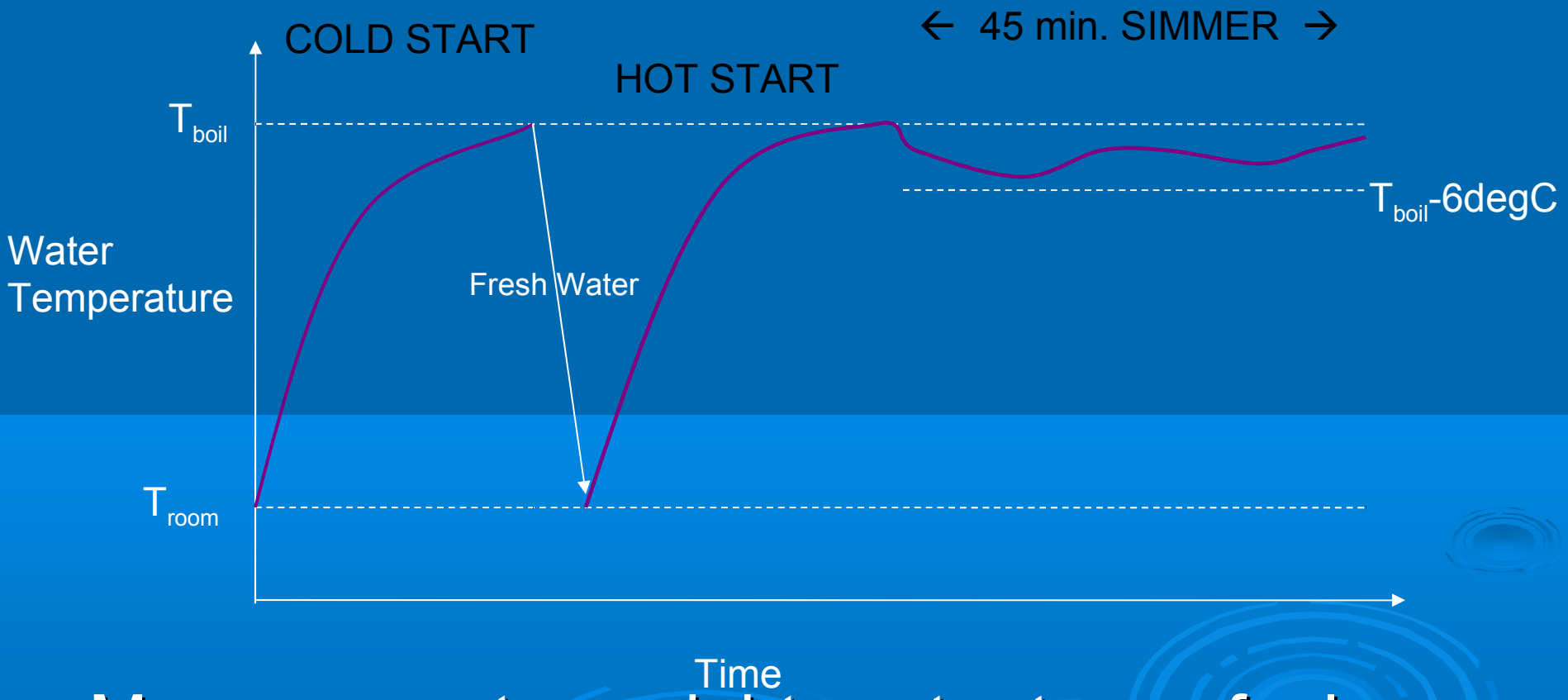
PEMS Flow Calibration

	Screen	Magnahelic
Fan Off		0
Fan On		0.43

Stove Name: Rwanda Mud 5.CSV
Test Number: 5
Notes/Dimensions: 4 sticks do Start → Thumb Cold Start
new sticks for hot start
Separate pan for hot start
Stick surface exposure
3rd piece stick touched bottom
Stove background

	Cold Start		Hot Start		Simmer	
	Start	End	Start	End	Start	End
Time	6:50	9:23	6:36	10:00	10:01	10:45
Weight Wood	2124	1765	1763	1509	1509	1161
Water Temp Pot 1	11.3	97.9	15.6	97.4	95	94
Water Temp Pot 2						
Water Temp Pot 3						
Water Temp Pot 4						
Weight Pot 1	2248	2065	2244	2079	2079	1371
Weight Pot 2						
Weight Pot 3						
Weight Pot 4						
Fire Starter	4 Pellets		5 Pellets			
Weight Charcoal + Container		29		—		39

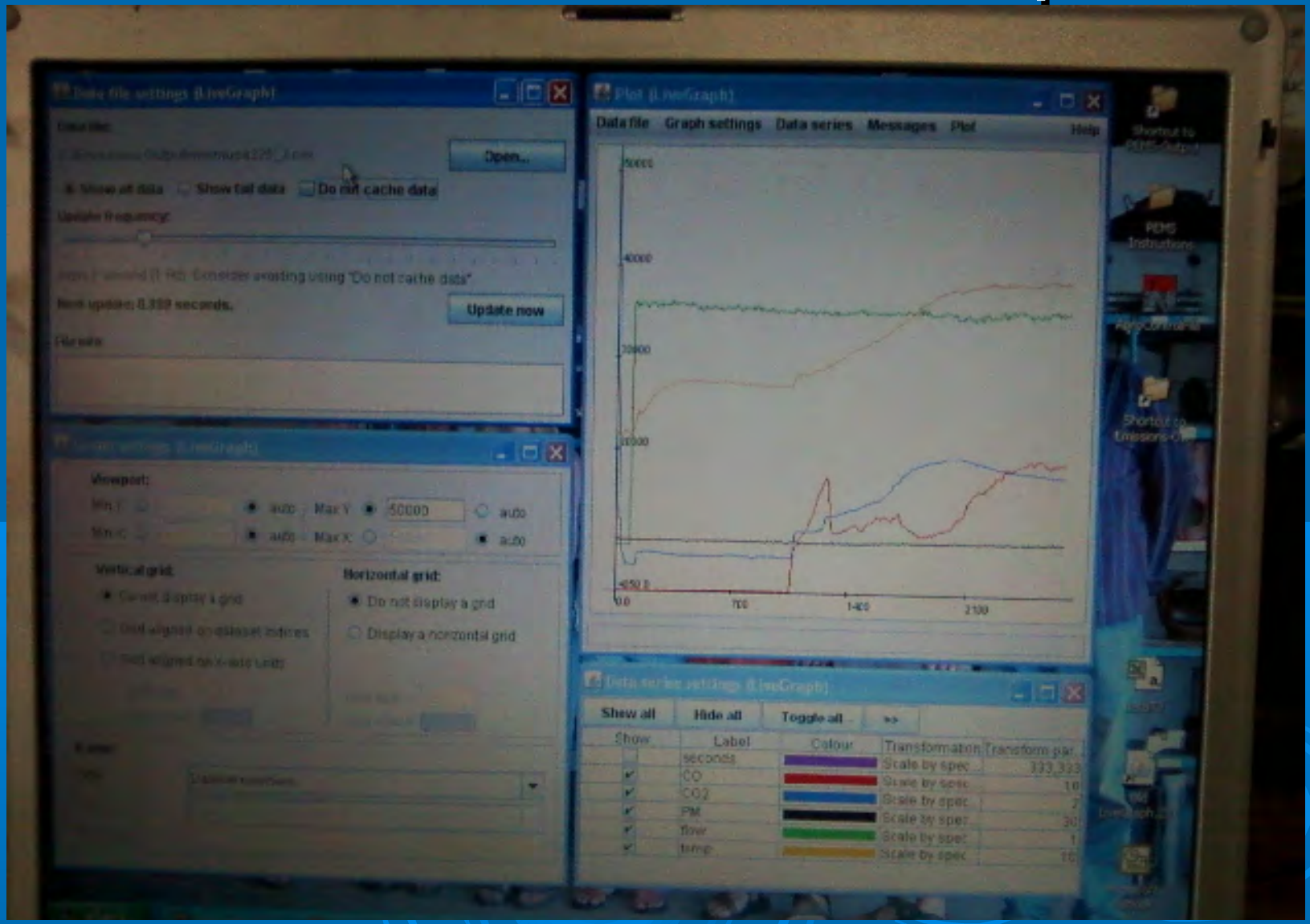
WBT Procedure



Measure: water weight, water temp, fuel weight, time.

Working with the PEMS

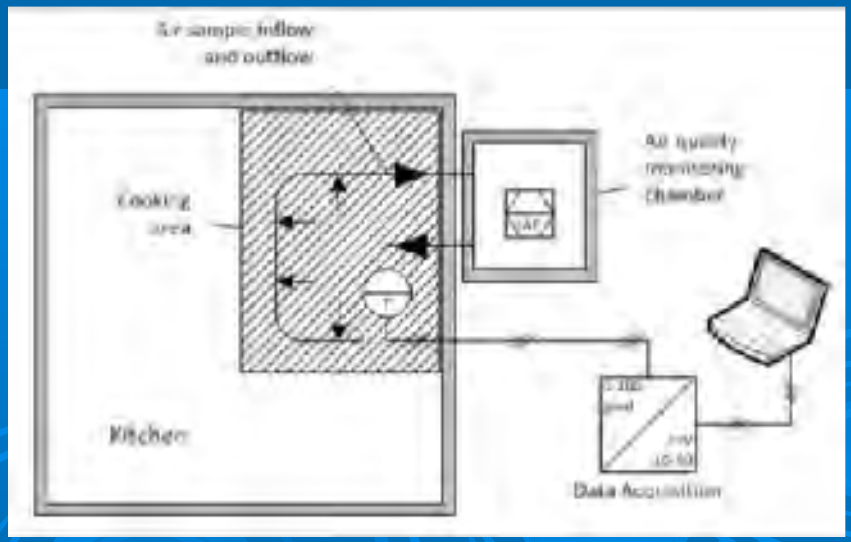
PEMS Realtime Output



Working with IAPM

On Person

In Room

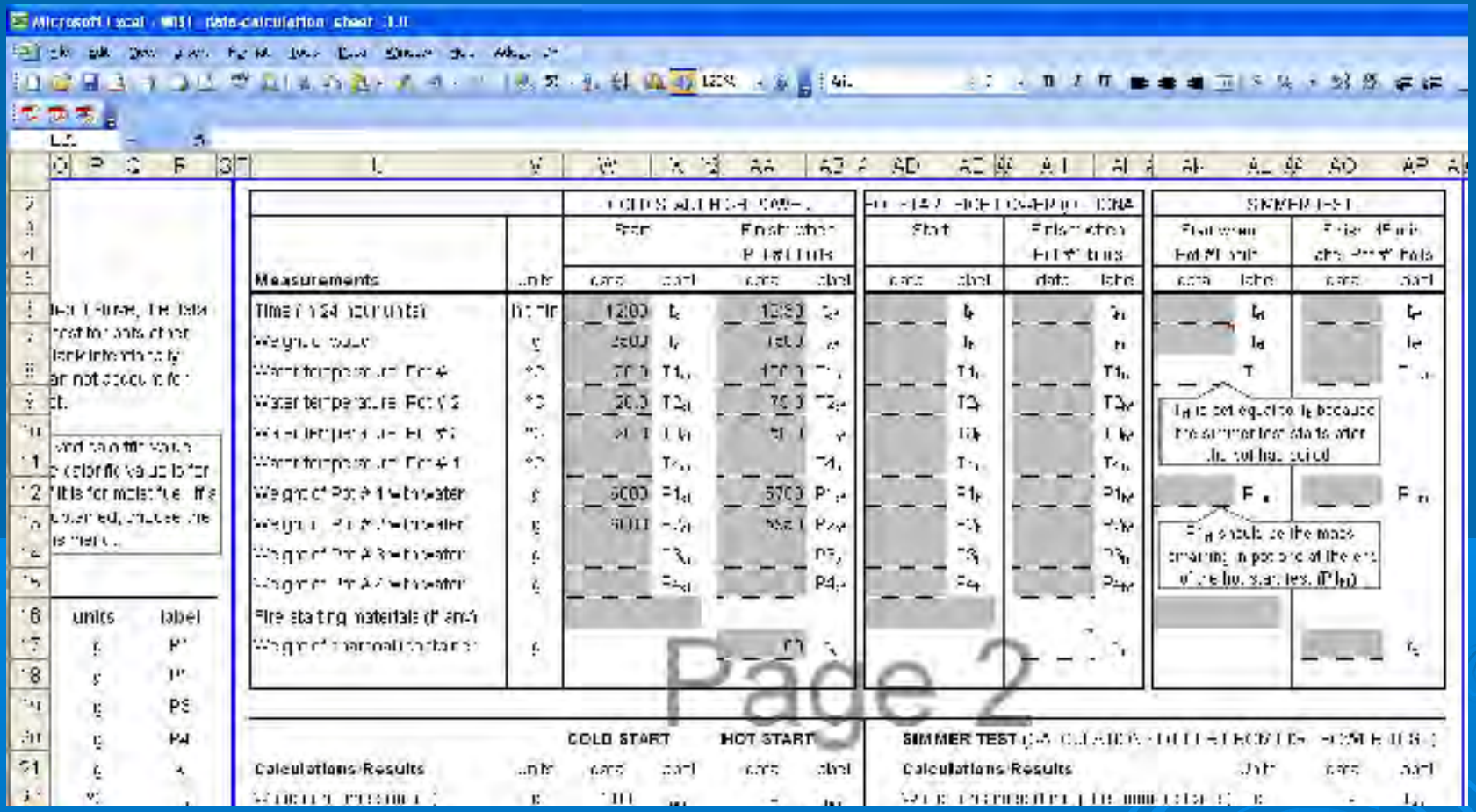


In Sample Chamber

WBT Results

		COLD START	
Calculations/Results	Units	data	label
Wood consumed (moist)	g	334	f_{cm}
Net change in char during test	g	-	Dc_c
Equivalent dry wood consumed	g	296.10552	f_{cd}
Water vaporized from all pots	g	198	w_{cv}
Effective mass of water boiled	g	4,802	w_{cr}
Time to boil Pot # 1	min	26	Δt_c
Thermal efficiency	--	0.37	h_c
Burning rate	g/min	11	r_{ch}
Specific fuel consumption	g/liter	62	SC_c
Temp-corr sp consumption	g/liter	57	SC^T_c
Temp-corr sp energy consumpt.	kJ/liter	1,105	SE^T_c
Firepower	watts	3,666	FP_c

WBT Data Processing



WBT Data Analysis

- Specific Fuel Consumption =

Starting Temperature Correction

Moisture Content Correction

Charcoal Correction

$$\frac{75}{(T_{boil}-T_{start})} X \left[Mass_{Wood} - Mass_{Moisture} - Mass_{\substack{\text{Wood Used} \\ \text{to Evaporate} \\ \text{Moisture}}} - 1.5*Char \right]$$

Mass of Water Boiled

Specific (per Liter) Correction

WBT Data Analysis

FUEL USE TO COMPLETE the 5L WBT =

5 x Average of Cold and Hot start Specific Consumption + Specific Consumption to Simmer

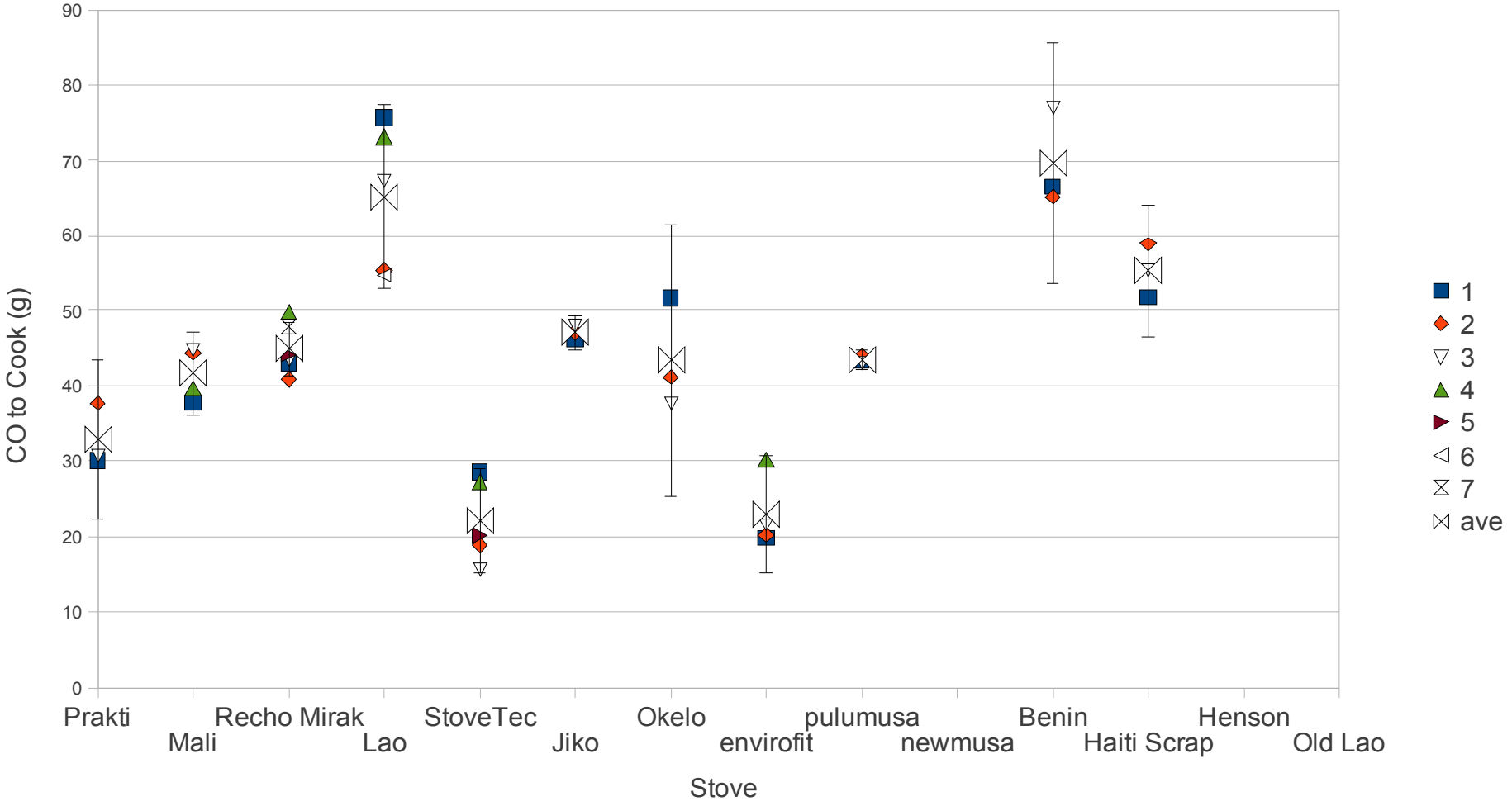
WBT Data Analysis

Energy Use (kJ) = Fuel Use (kg) * **Calorific Value (kJ/kg)**

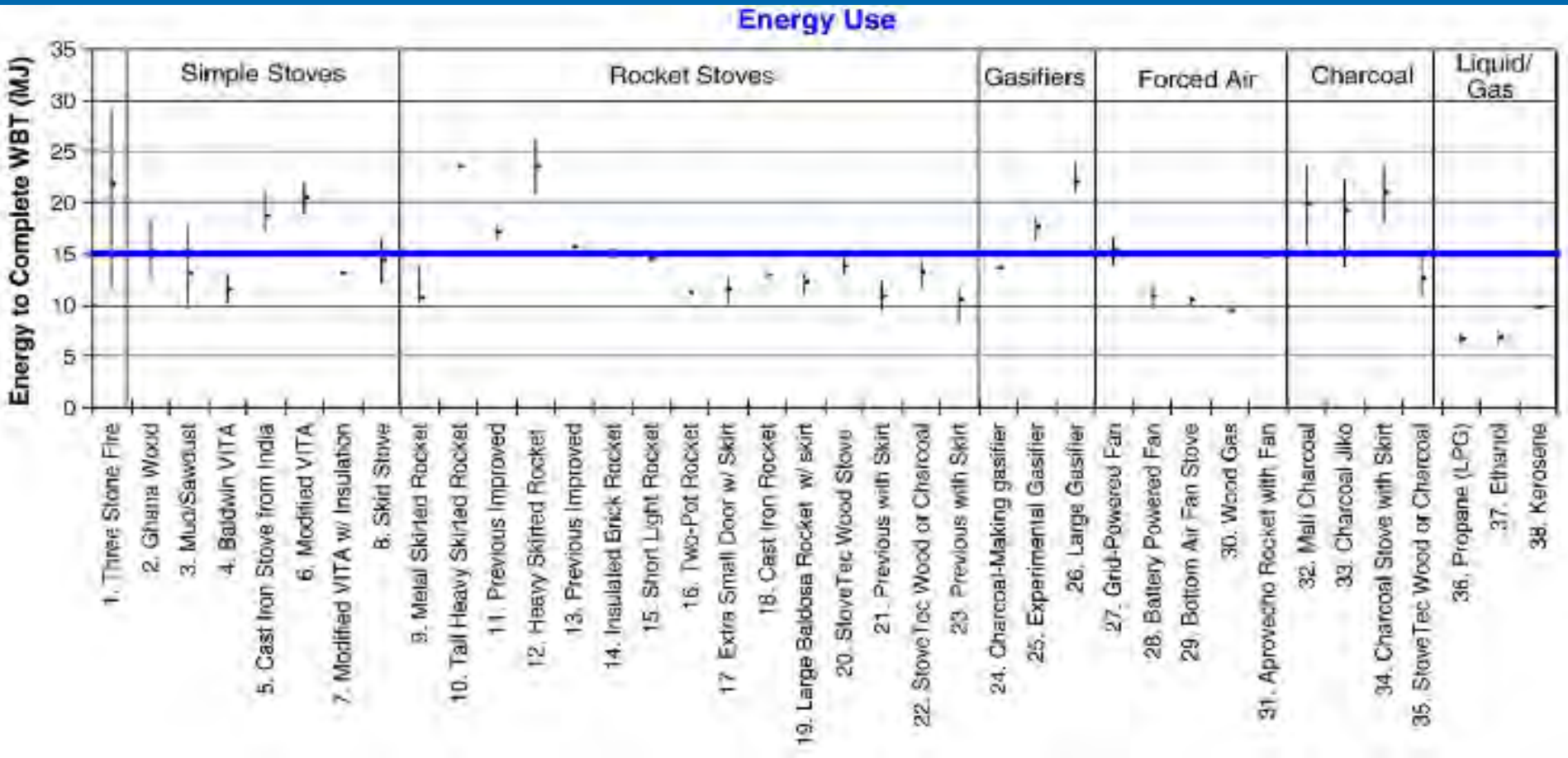
Standard Performance Measures

Standard Performance Measures		Mali	Mali	Mali	Mali	ave	stdev	cov
Fuel to Cook 5L (850/1500)	g	244.7	219.0	230.5	213.6	222.69	6.77	3.04%
CO to Cook 5L (20)	g	59.5	75.6	73.6	78.5	75.91	2.48	3.27%
PM to Cook 5L (1500)	mg	4.5	10.7	-9.9	331.8	110.90	191.58	172.76%
Energy to Cook 5L (15,000/25,000)	kJ	6,870	6,149	6,473	6,139	6253.11	190.18	3.04%
Time to Boil	min	26.3	40.2	35.1	40.5	38.60	3.01	7.81%
CO2 to Cook 5L	g	471.2	529.2	490.8	517.6	512.53	19.66	3.84%

Sample Size and Distribution



Uses


Energy Use
Energy to Complete WBT (MJ)
0
5
10
15
20
25
30
35
Simple Stoves
Rocket Stoves
Gasifiers
Forced Air
Charcoal
Liquid/ Gas
1. Three Stone Fire
2. Ghana Wood
3. Mud/Sawdust
4. Baldwin VITA
5. Cast Iron Stove from India
6. Modified VITA
7. Modified VITA w/ Insulation
8. Skirt Stove
9. Metal Skirted Rocket
10. Tall Heavy Skirted Rocket
11. Previous Improved
12. Heavy Skirted Rocket
13. Previous Improved
14. Insulated Brick Rocket
15. Short Light Rocket
16. Two-Pot Rocket
17. Extra Small Door w/ Skirt
18. Cast Iron Rocket
19. Large Balbosa Rocket w/ skirt
20. StoveTec Wood Stove
21. Previous with Skirt
22. StoveTec Wood or Charcoal
23. Previous with Skirt
24. Charcoal-Making gasifier
25. Experimental Gasifier
26. Large Gasifier
27. Grid-Powered Fan
28. Battery Powered Fan
29. Bottom Air Fan Stove
30. Wood Gas
31. Aprovecho Rocket with Fan
32. Mali Charcoal
33. Charcoal Jiko
34. Charcoal Stove with Skirt
35. StoveTec Wood or Charcoal
36. Propane (LPG)
37. Ethanol
38. Kerosene

WBT Supplies

- Standard Testing Pot holding 5L of water
- Scale (10-15 kg capacity, 1-2 gram resolution)
- Thermometer/Thermocouple (with fast response)
- At least 3 kilos of testing wood per test
- 10L or more of room-temperature water
- Metal Tray for Weighing Charcoal
- Tools for removing charcoal (tongs, spatula)
- Heat resistant gloves

Major Strength
Common Basis for Comparison

Sunken Pot Mud

Charcoal

Institutional

Major Limitation

Field Correlations

End Result...

Beautiful Stove