FORCE TECHNOLOGY

Factors controlling condensed phase emissions from gas engine fired combined heat and power plant (CHP) – a field study

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Objective

The primary objective of this study was to identify the primary causes of fine and ultra fine particles emitted from CHP plants using gas fired engines. Through an extensive field measurement program, the most important factors influencing particle emission were assessed. To identify which operational parameters has the greatest influence on the particulate emission from gas engines, the measurement program included collection of relevant engine operating parameters as well as measurement of relevant gas and particulate phase components.

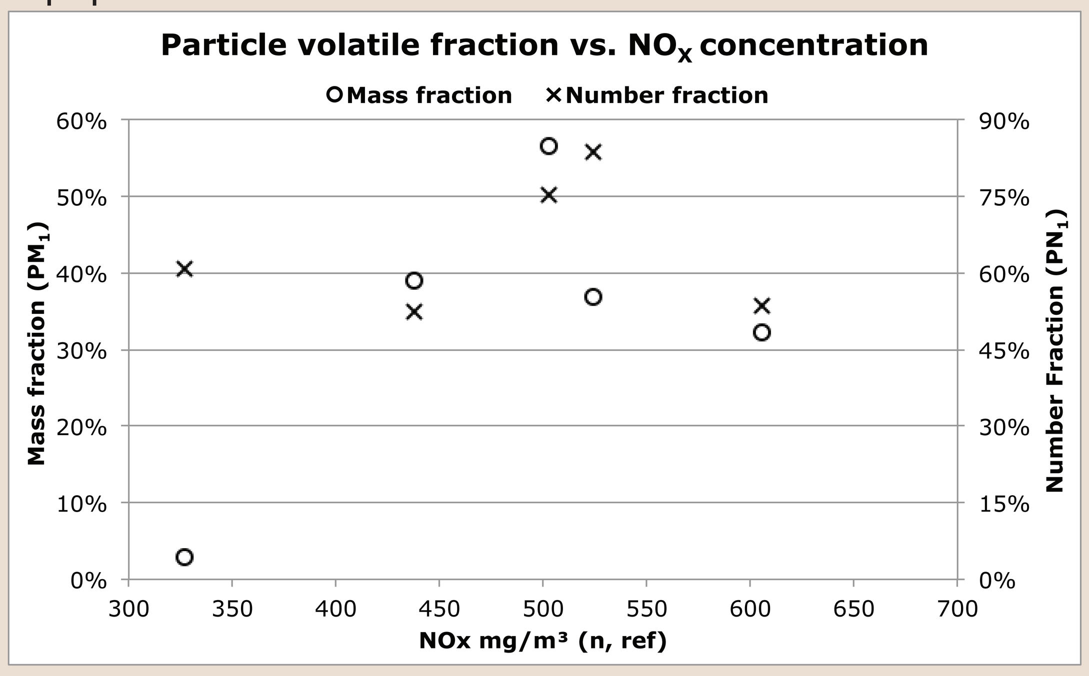
Measurement program

The presented work is based on a measurement program comprised of a total of 7 field measurement campaigns conducted over a time span of 13 month at 5 Combined Heat and Power (CHP) plants at selected locations in Denmark.

Site	Engine type (Brand)	Engine load (kW)	Engine lubricant (Brand)	Base oil group (API definition)	Oil consumption (g/kWh)
Jelling	Wärtsilä 18V34SG	6074	Shell Mycella	2	0.160
Christiansfeld	RR type K	3118	Geotex PX40	3	0.107
Aså	RR type K	2066	Geotex PX40	3	0.409
Frederikssund	Wärtsilä 18V34SG	4794	Mobil 805	3	0.146
Brønderslev	RR type K	3271	Q8 Mahler	3	0.080

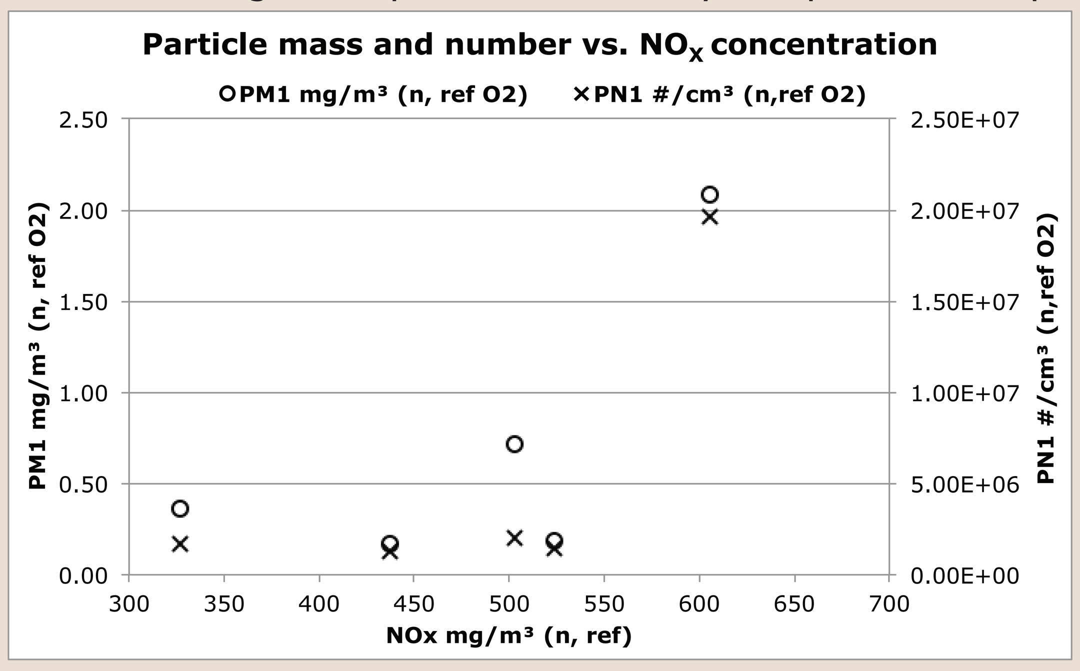
Volatile particle fraction

Using a Thermodenuder (Dekati), all volatile species in the gas phase were stripped from the extracted aerosol sample at 300 °C before being passed on to the analysis equipment.



Particle concentration I

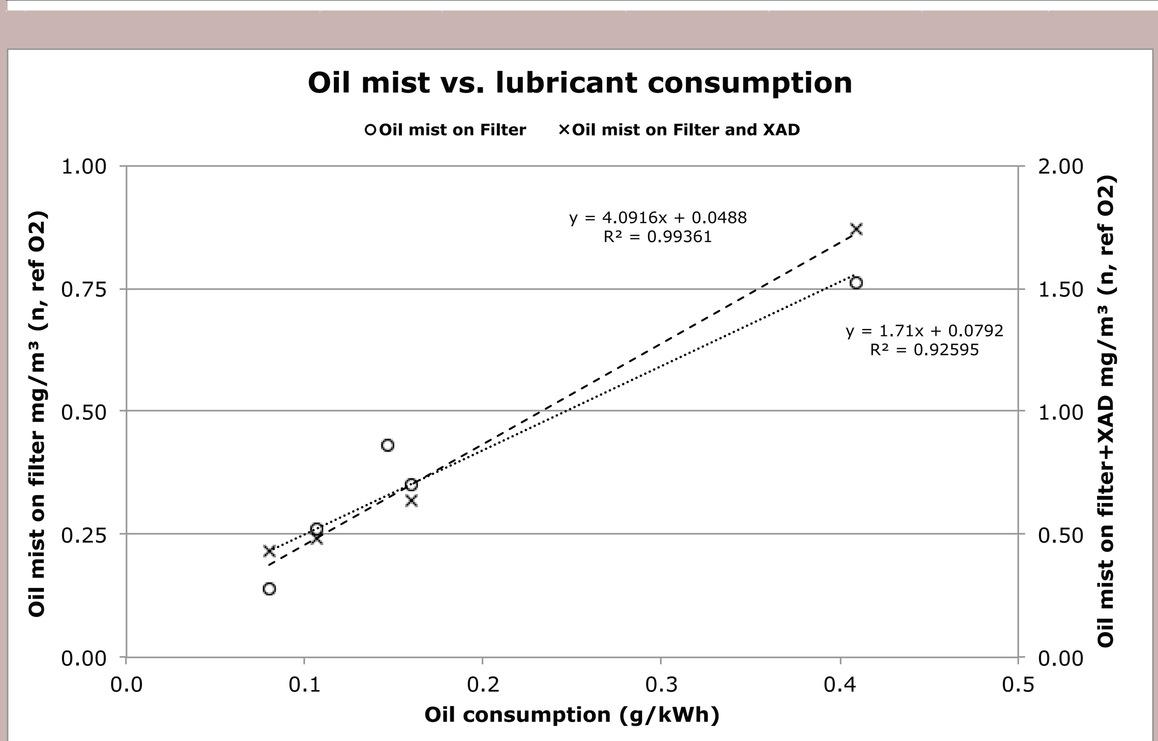
The particle number concentration was measured usinge an electrostatic low pressure impactor (ELPI, Dekati). The mass concentration was then subsequently inferred using asumptions on density andparticle shape.



Oil mist measurements

The table shows the average of the results from the 7 individual campaigns which comprised a total of 20 separate oil mist samples. The samples were collected on heated (120 °C) glass fiber filter followed by a condencer and a absorption column packed with Amberlite XAD-2 resin beads. The collected samples are subsequently extracted and the collected amount of oil is determined using GC-FID analysis. The fraction collected on the filter is used primarily for data analysis in this work. However, in some instances, the fraction collected on the XAD column has also been considered in order to provide a more thorough analysis. Shown in the table is also measured values for oil consumption, NOX, unborned hydrocarbons (UHC) along with particle number and mass concentration. The results shown in light shaded boxes indicate that the values were not measured simultaneously with the oil mist samples, but during the following day of the same campaign. The result show in the dark grey shading is considered to be an outlier.

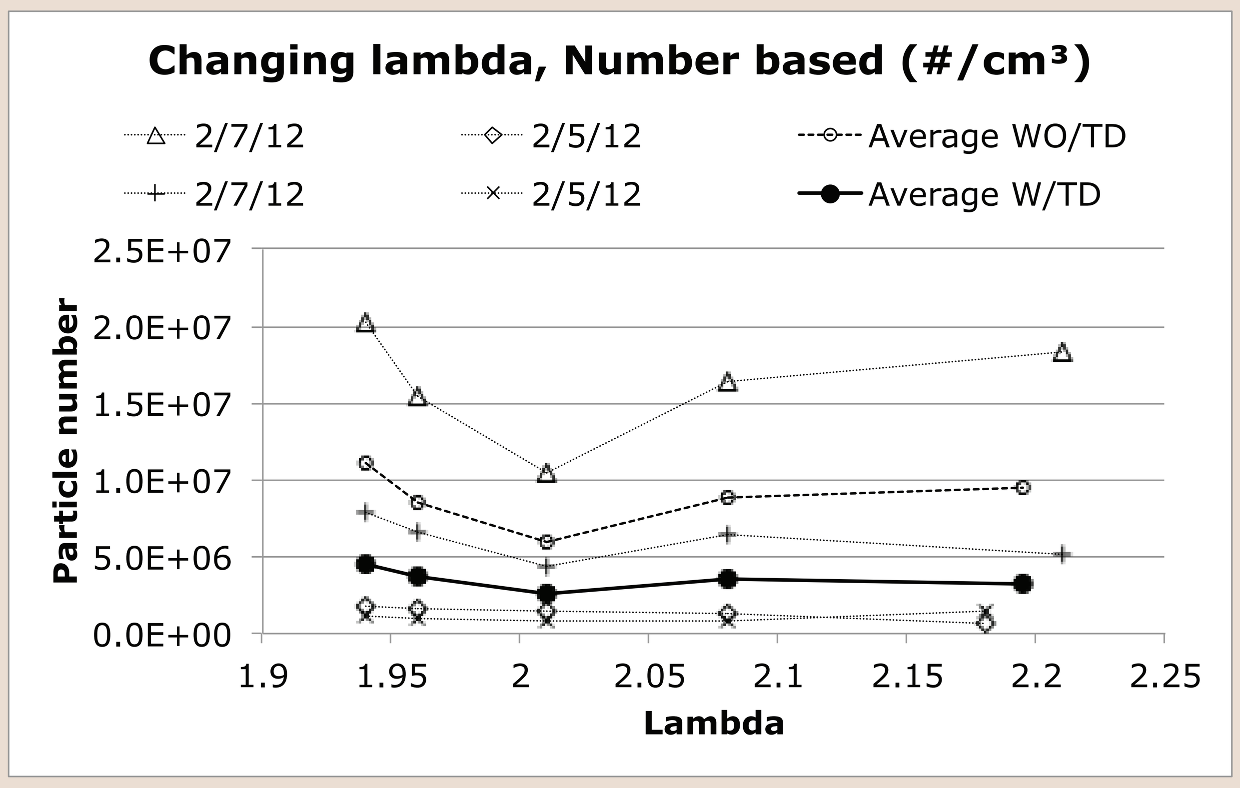
Site	Field test #	Oil consumption (g/kWh)	NOx mg/m³ (n, ref)	UHC mgC/m³ (n, ref)	Number based: PN1 #/cm³ (n,ref O2)	Number based: Oil fraction (PN1)	Mass based: PM1 mg/m³ (n, ref O2)	Mass based: Oil fraction (PM1)	Mass based: Oil fraction (PM10)	Oil mist: Oil mist on filter mg/m³ (n, ref O2)	Oil mist: Oil mist on XAD mg/m³ (n, ref O2)	Oil mist: Oil mist on filter+XAD mg/m³ (n, ref O2)
Jelling	1	0.160	327	1016	1.66E+06	61%	0.36	3%	42%	0.35	0.29	0.64
Jelling	2	-	-	-	-	-	-	-	-	0.11	0.07	0.18
Christiansfeld	3	0.107	503	1511	1.99E+06	75%	0.72	57%	74%	0.26	0.22	0.48
Aså	4	0.409	524	1812	1.49E+06	84%	0.19	37%	42%	0.76	0.98	1.74
Frederikssund	5	0.146	606	1135	1.96E+07	54%	2.08	32%	48%	0.43	3.85	4.28
Brønderslev, before	6	0.080	438	1589	1.31E+06	52%	0.17	39%	60%	0.14	0.29	0.43
Brønderslev, after	7	-	332	1593	8.81E+06	49%	0.26	39%	46%	0.12	0.05	0.17

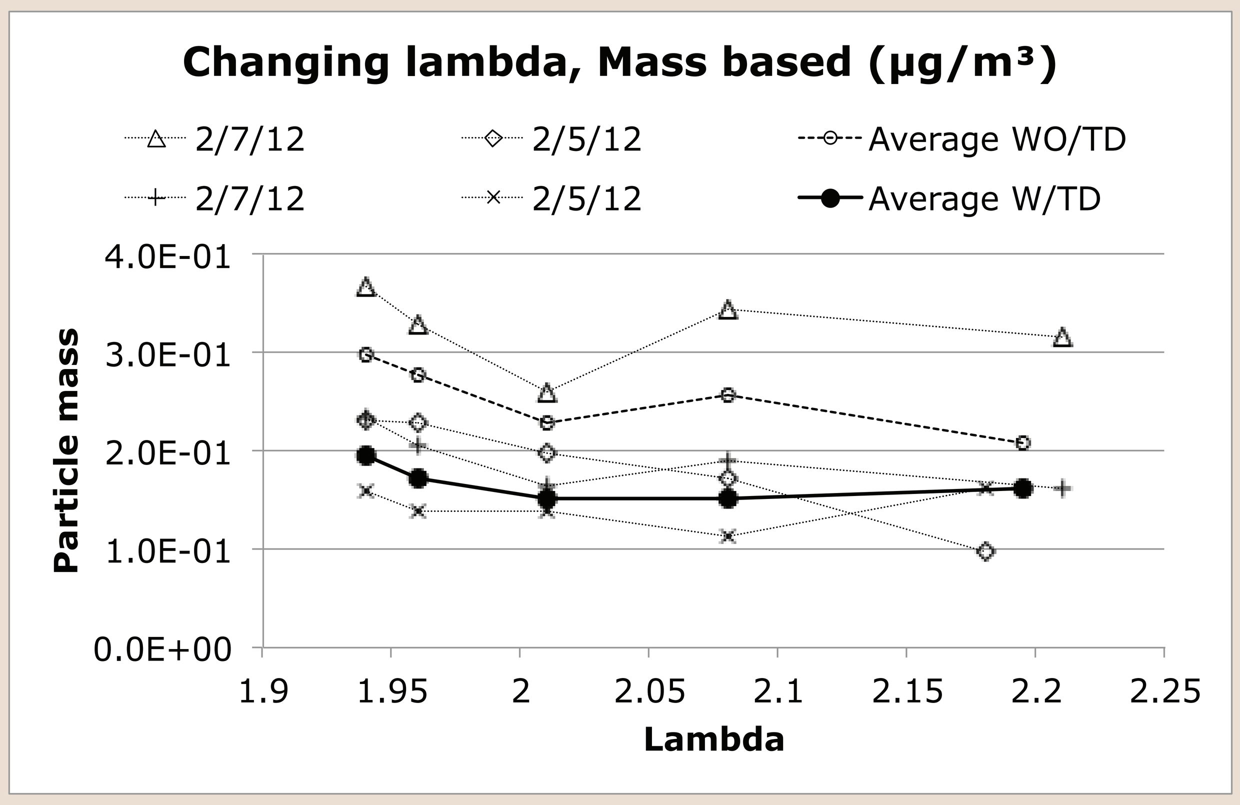


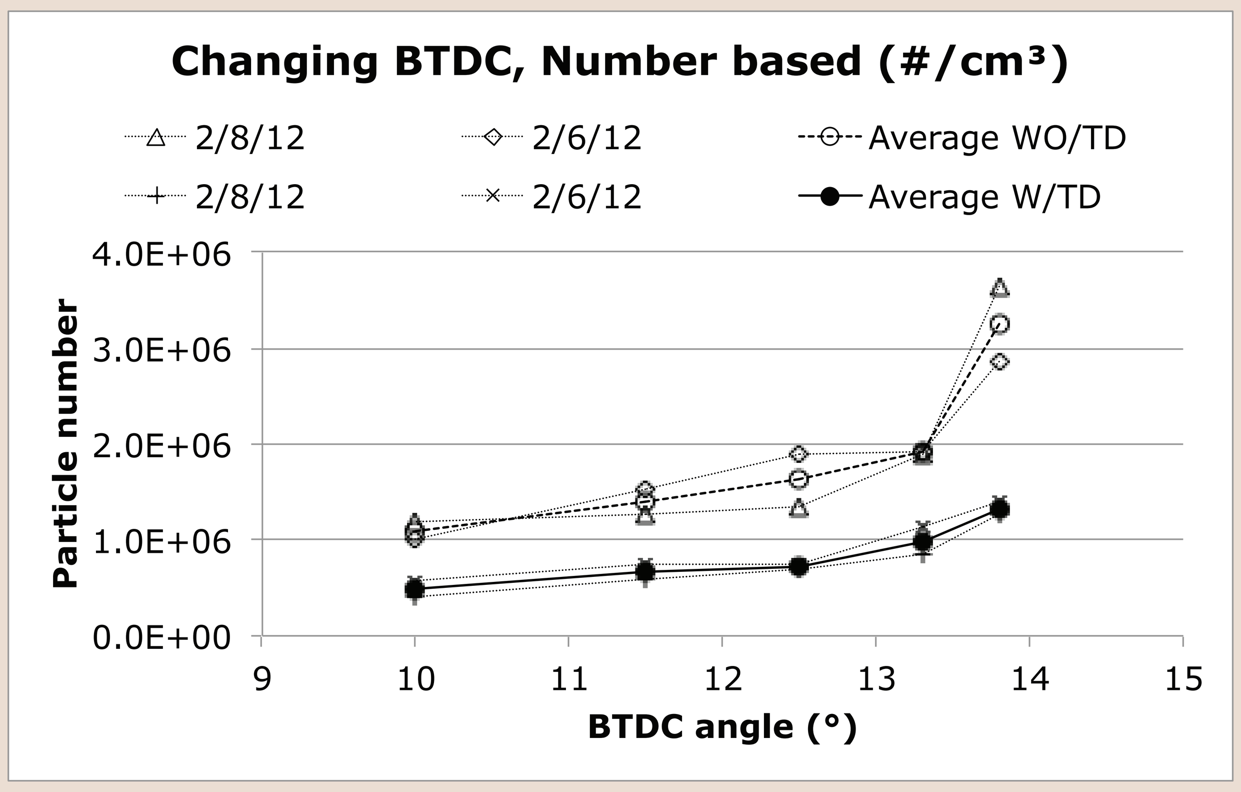
The graph shows the correlation between measured oil mist in the stack gas and the lubricant consumption. The open circles indicate results where only the filter samples are included; the crosses also include the fraction collected on the XAD column. A strong correlation between oil mist measured and engine lubricant consumption was found, with the stronger correlation found when the gas phase was included. No other significant correlations were found between the oil mist results and other measured parameters in this work.

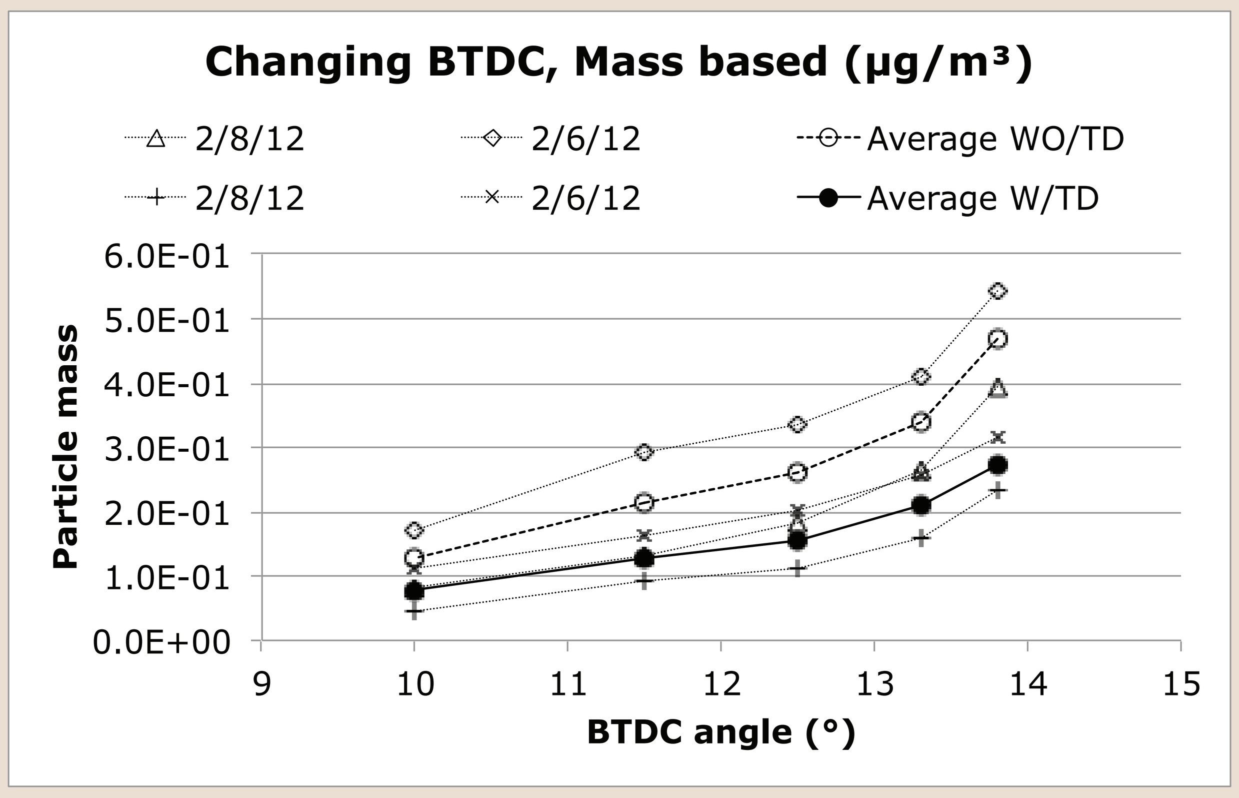
Particle concentration II

The NO_X concentration can be controlled either by changing the air to fuel ratio (Lambde) or by changing the crank angle at which the spark initiated the combustion (measured as before top dead center (BTDC).









Main findings

No correlation between PM_{10}/PN_{10} and NO_X level
No correlation between PN_1 and NO_X level
Some correlation between PM_1 and NO_X level
No/weak correlation between PM_1/PN_1 and Lambda (fuel to air ratio)
Strong correlation between PM_1/PN_1 and BTDC (before top dead center)
Strong correlation between oil mist and consumption
No other correlation was found to oil mist measured

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