EC/OC of CAST generated soot

Dr. Lianpeng Jing

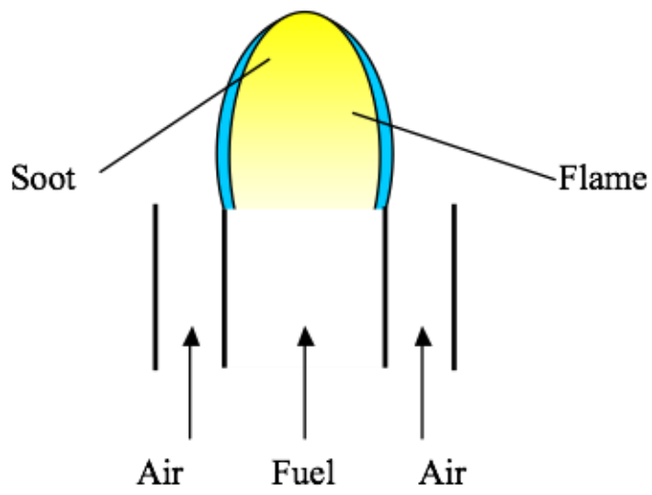
JING Ltd.
Switzerland

50th PMP Meeting, April 3-4, 2019
Centre Albert Borschette
Brussels Belgium

Contents

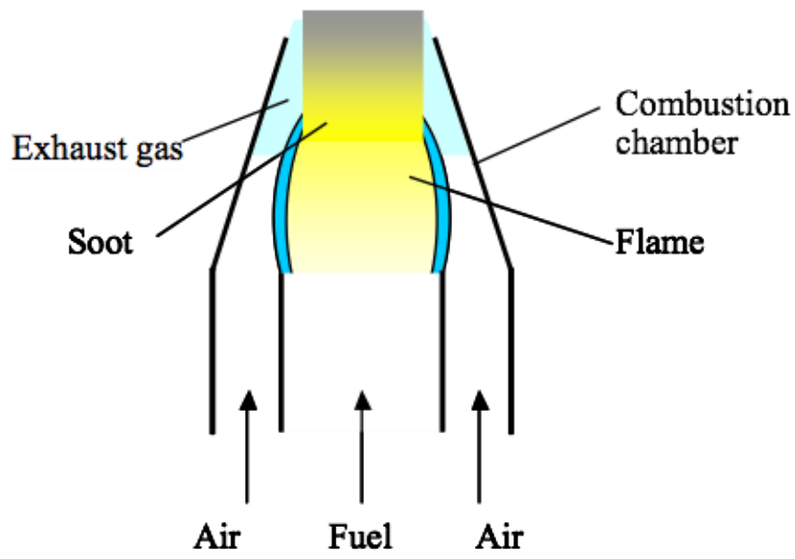
1. Understand the flame in miniCAST
- principle

- Soot formed in a well controlled flame
- Growth of soot particle
- Soot stabilized by N_2 as quench gas
- Dilution



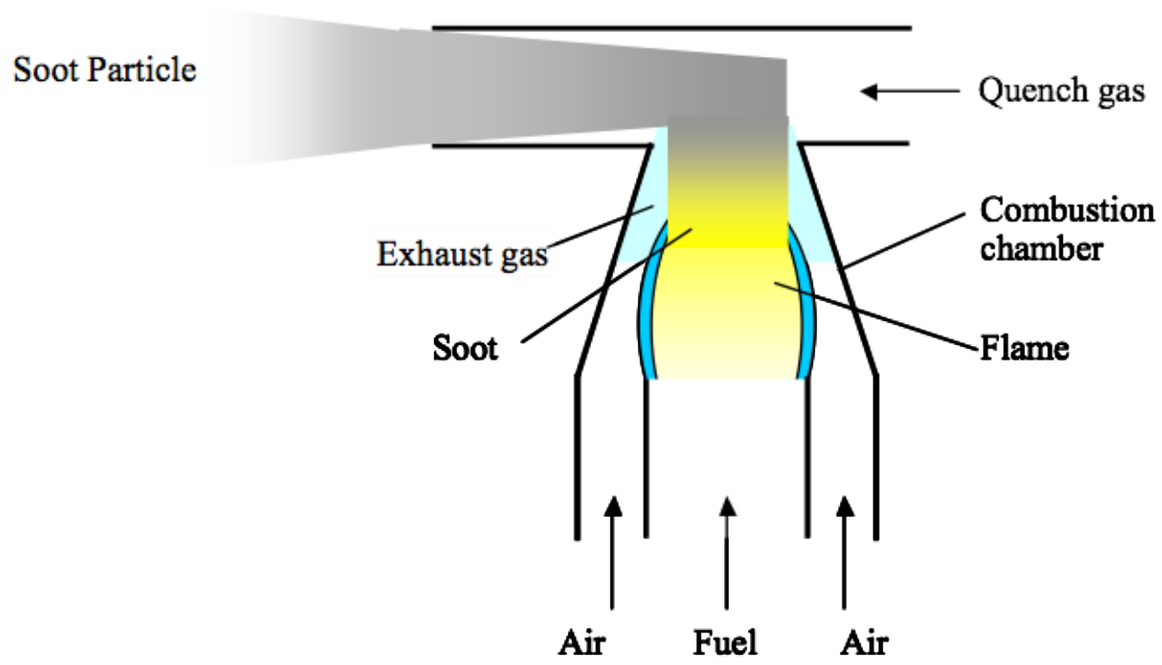
1. Understand the flame in miniCAST
- principle

- Soot formed in a well controlled flame
- Growth of soot particle
- Soot stabilized by N_2 as quench gas
- Dilution



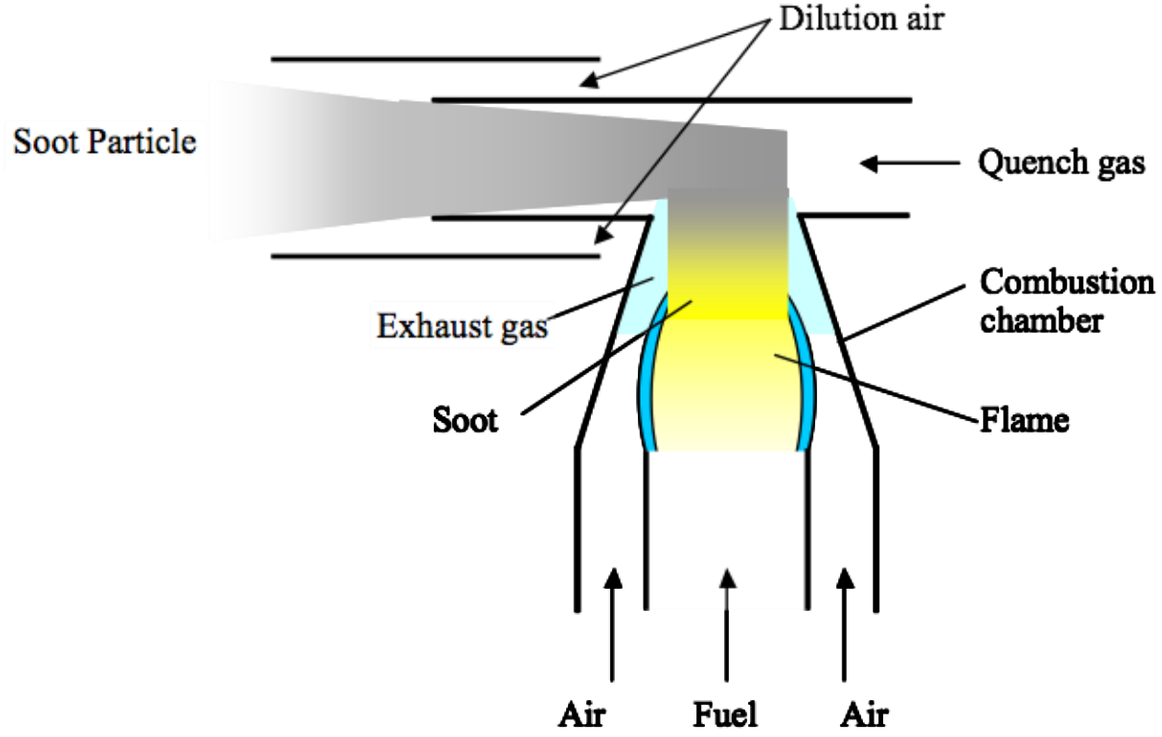
1. Understand the flame in miniCAST
- principle

- Soot formed in a well controlled flame
- Growth of soot particle
- Soot stabilized by N_2 as quench gas
- Dilution



1. Understand the flame in miniCAST
- principle

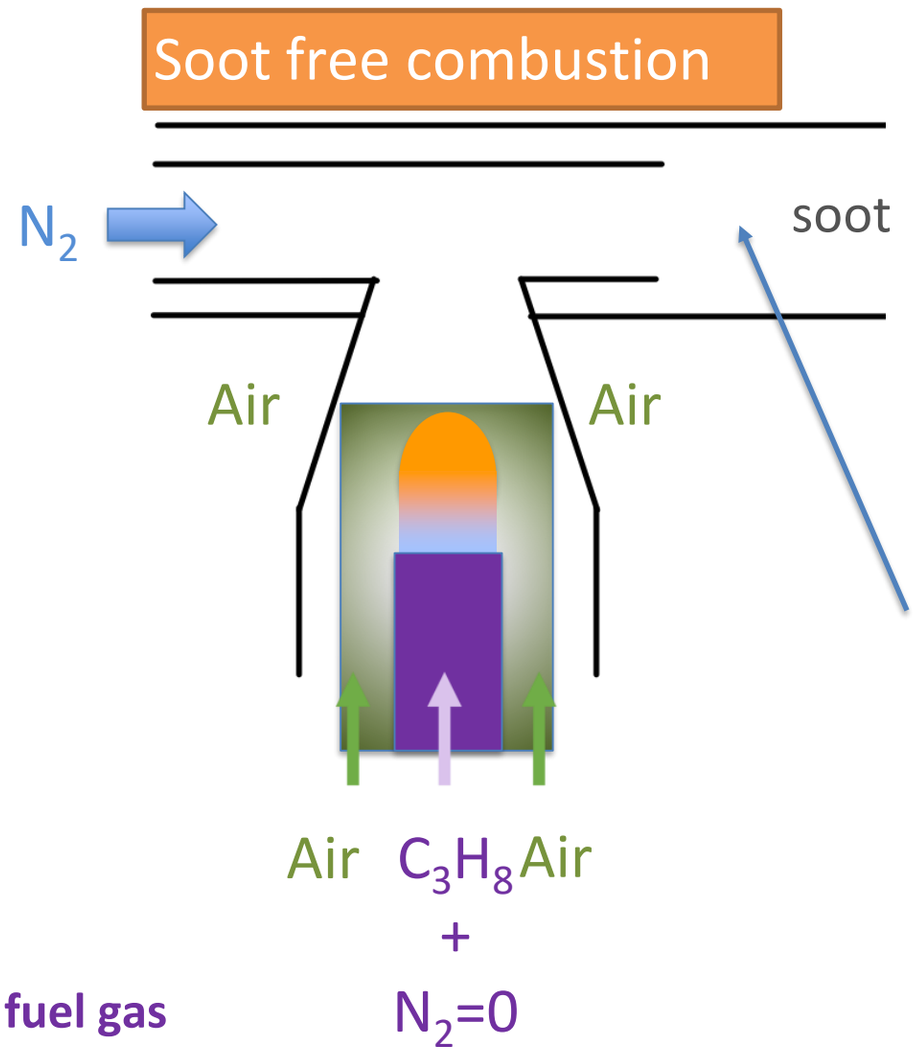
- Soot formed in a well controlled flame
- Growth of soot particle
- Soot stabilized by N_2 as quench gas
- Dilution



1. Understand the flame in miniCAST

- soot from a fuel-lean flame

Quench gas with constant value set by manufacturer



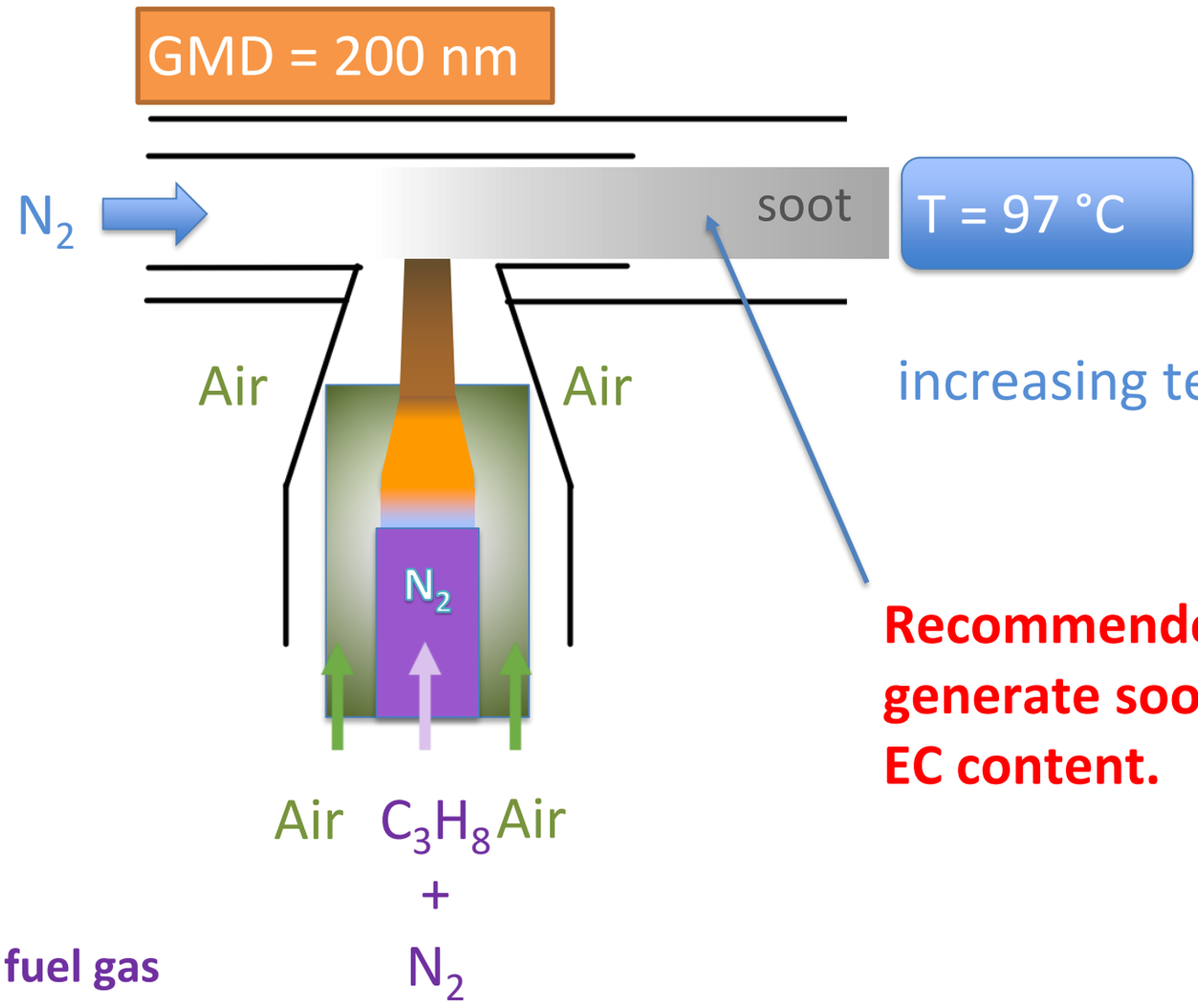
Recommended way to generate soot with high EC content.

Fuel-lean flame by diluting the fuel gas

1. Understand the flame in miniCAST

- soot from a fuel-lean flame

Quench gas with constant value set by manufacturer



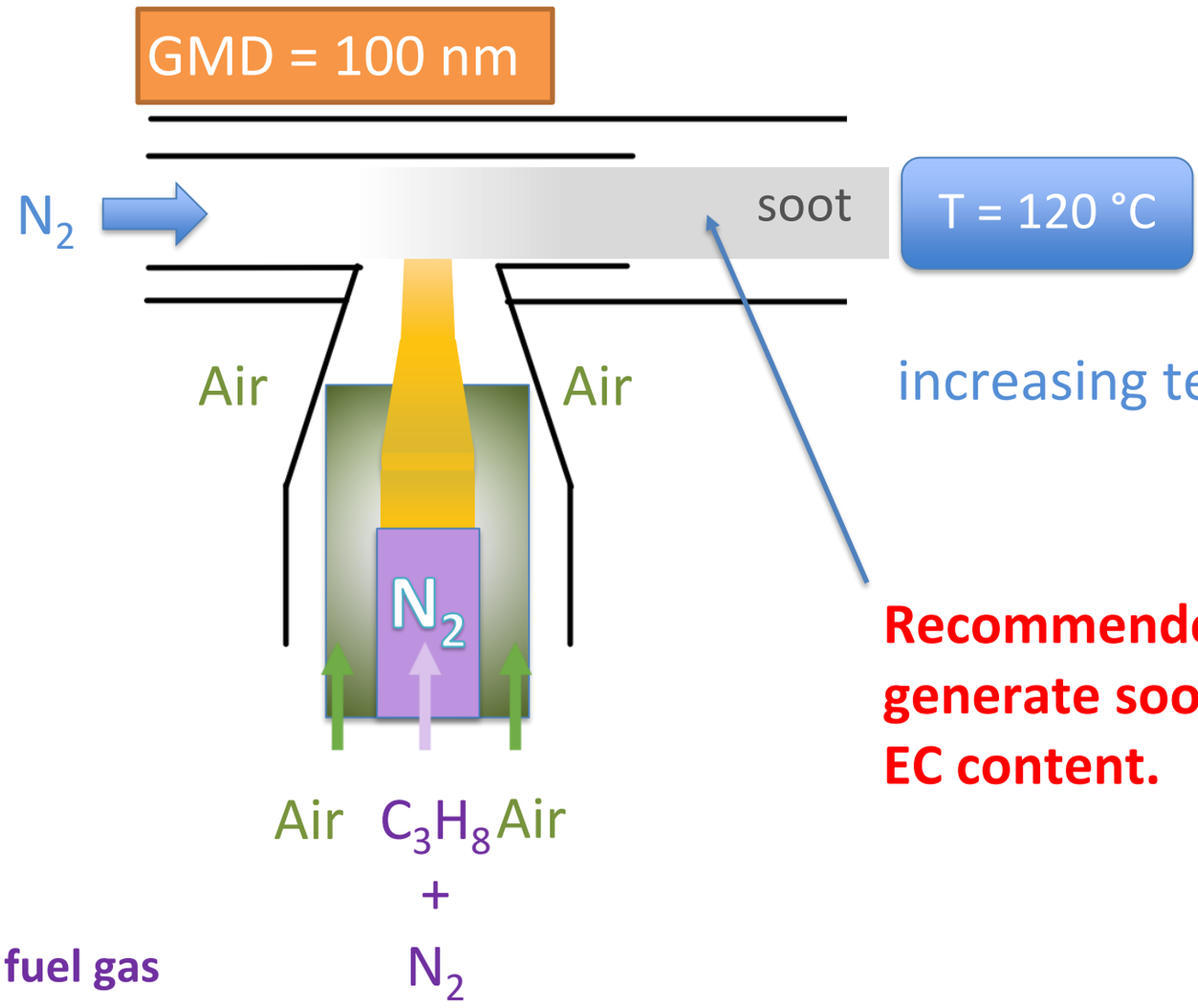
Recommended way to generate soot with high EC content.

Fuel-lean flame by diluting the fuel gas

1. Understand the flame in miniCAST

- soot from a fuel-lean flame

Quench gas with constant value set by manufacturer



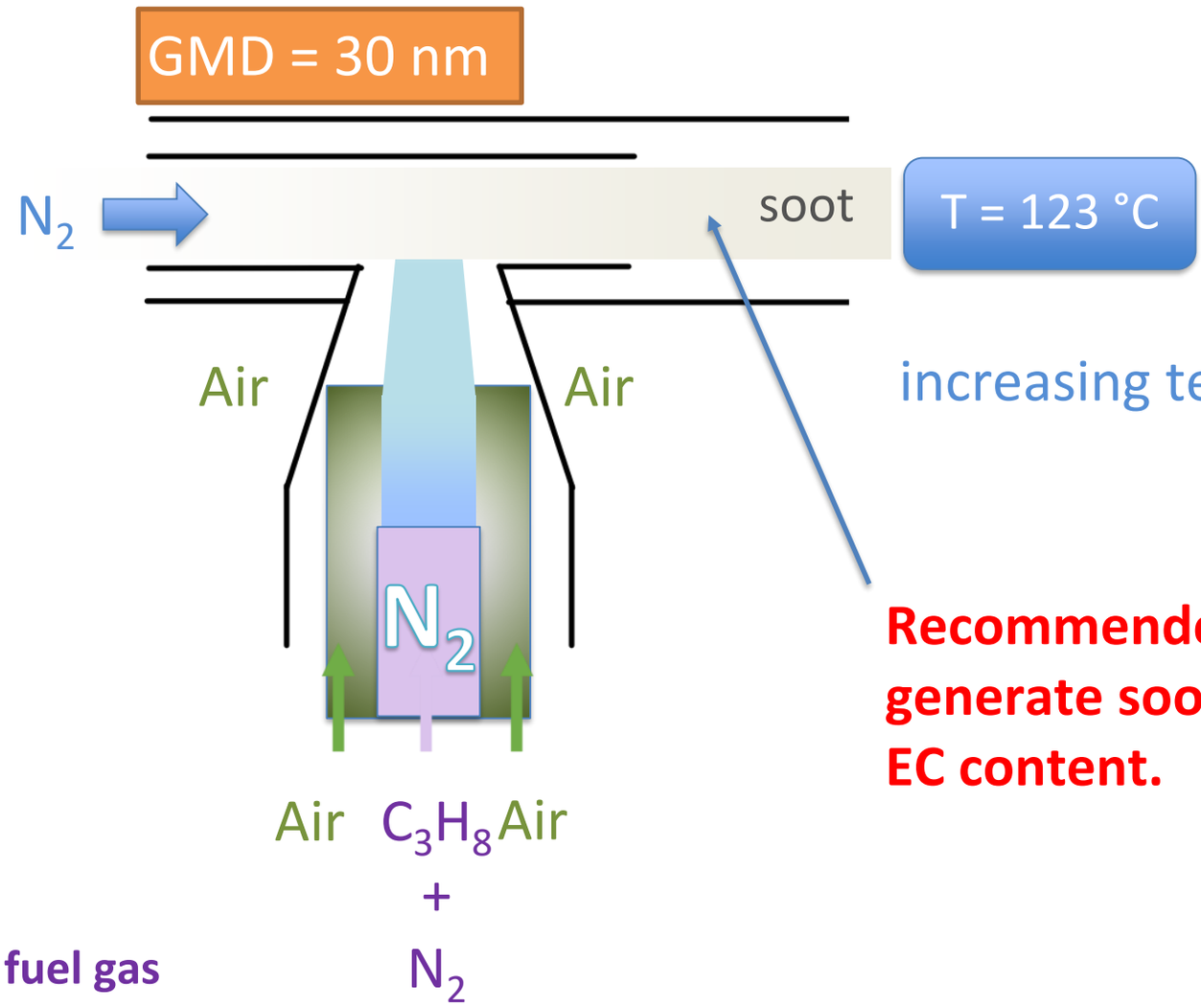
Recommended way to generate soot with high EC content.

Fuel-lean flame by diluting the fuel gas

1. Understand the flame in miniCAST

- soot from a fuel-lean flame

Quench gas with constant value set by manufacturer



Recommended way to generate soot with high EC content.

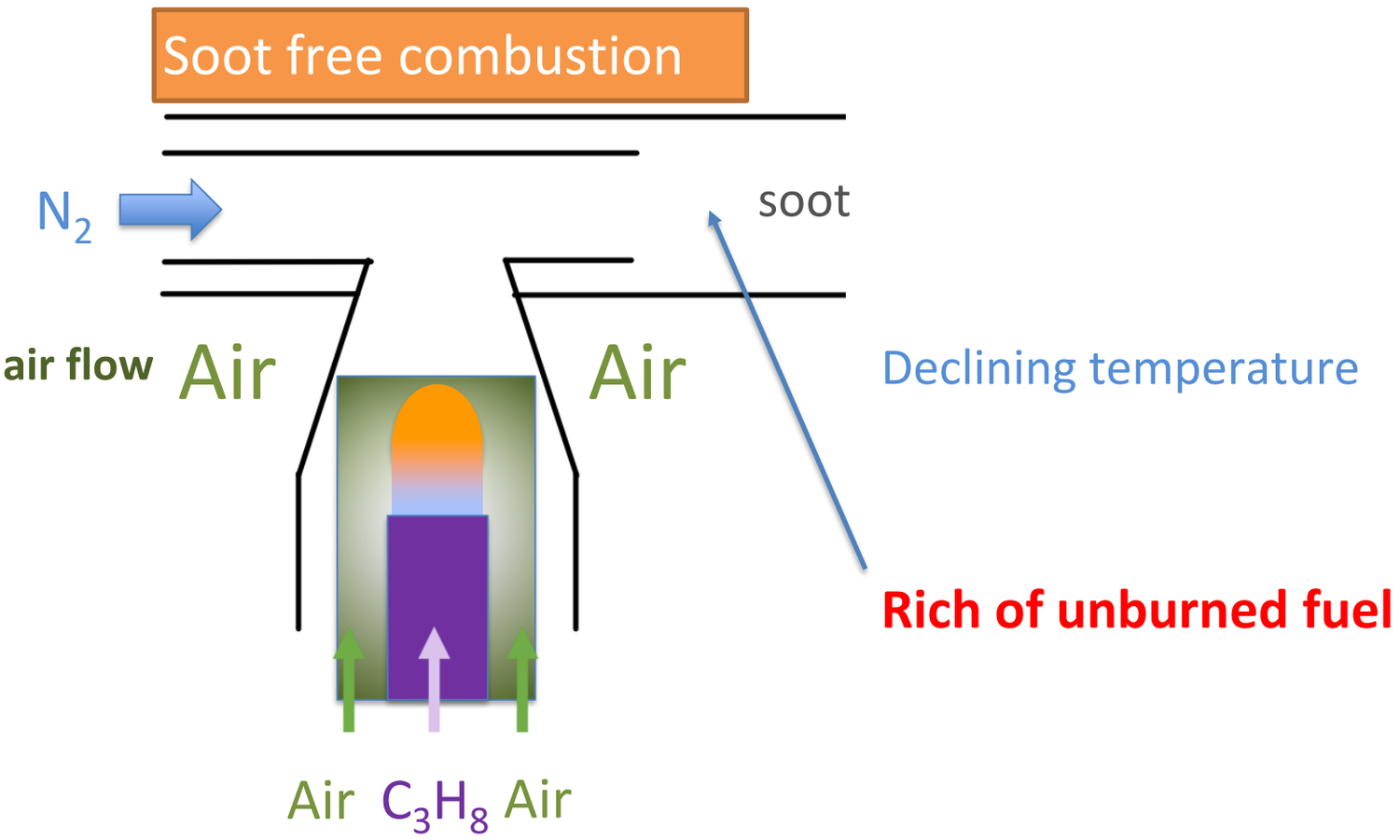
Fuel-lean flame by diluting the fuel gas

1. Understand the flame in miniCAST

- soot from a fuel-rich flame

Quench gas with constant value set by manufacturer

Fuel-rich flame by reducing the air flow

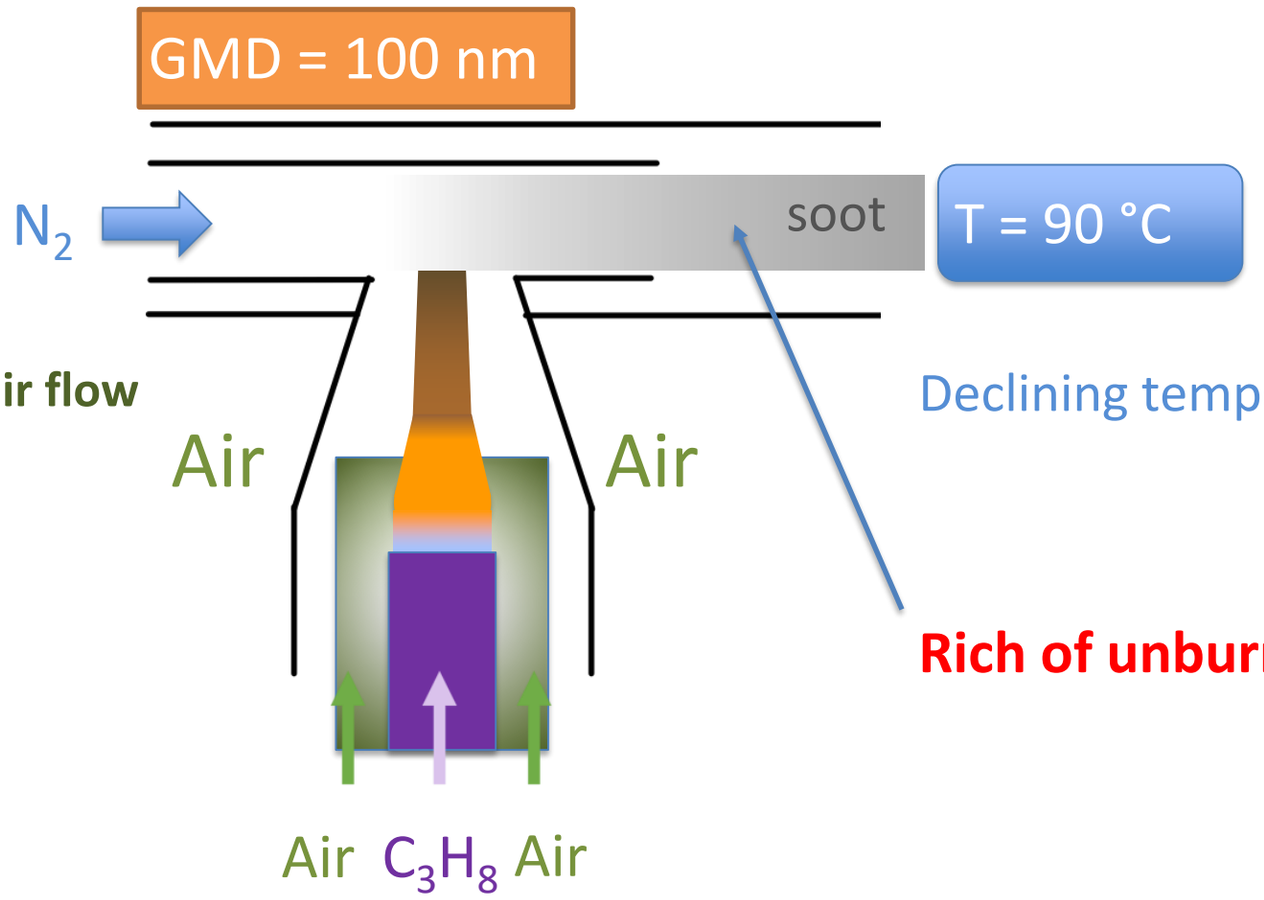


1. Understand the flame in miniCAST

- soot from a fuel-rich flame

Quench gas with constant value set by manufacturer

Fuel-rich flame by reducing the air flow

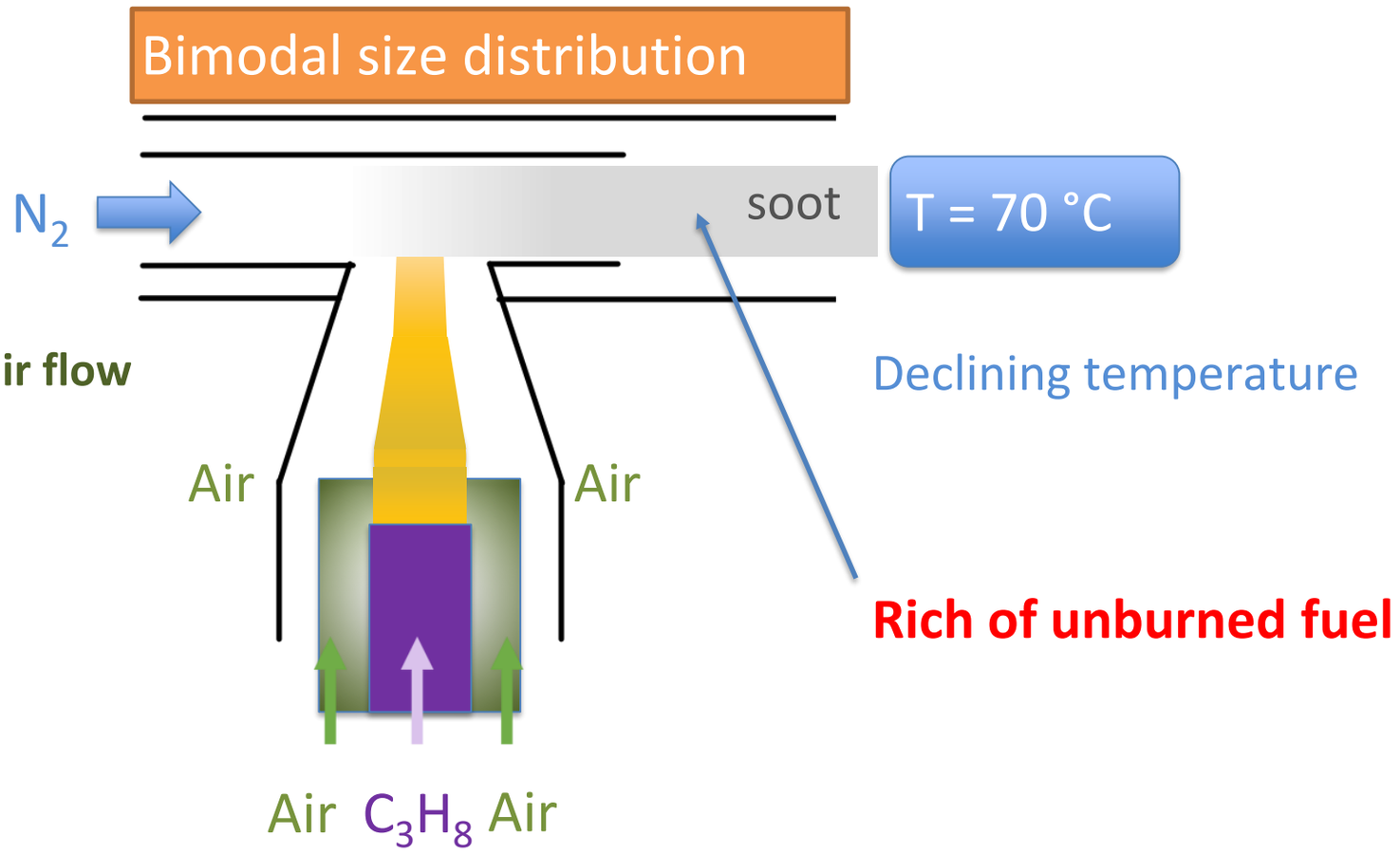


1. Understand the flame in miniCAST

- soot from a fuel-rich flame

Quench gas with constant value set by manufacturer

Fuel-rich flame by reducing the air flow

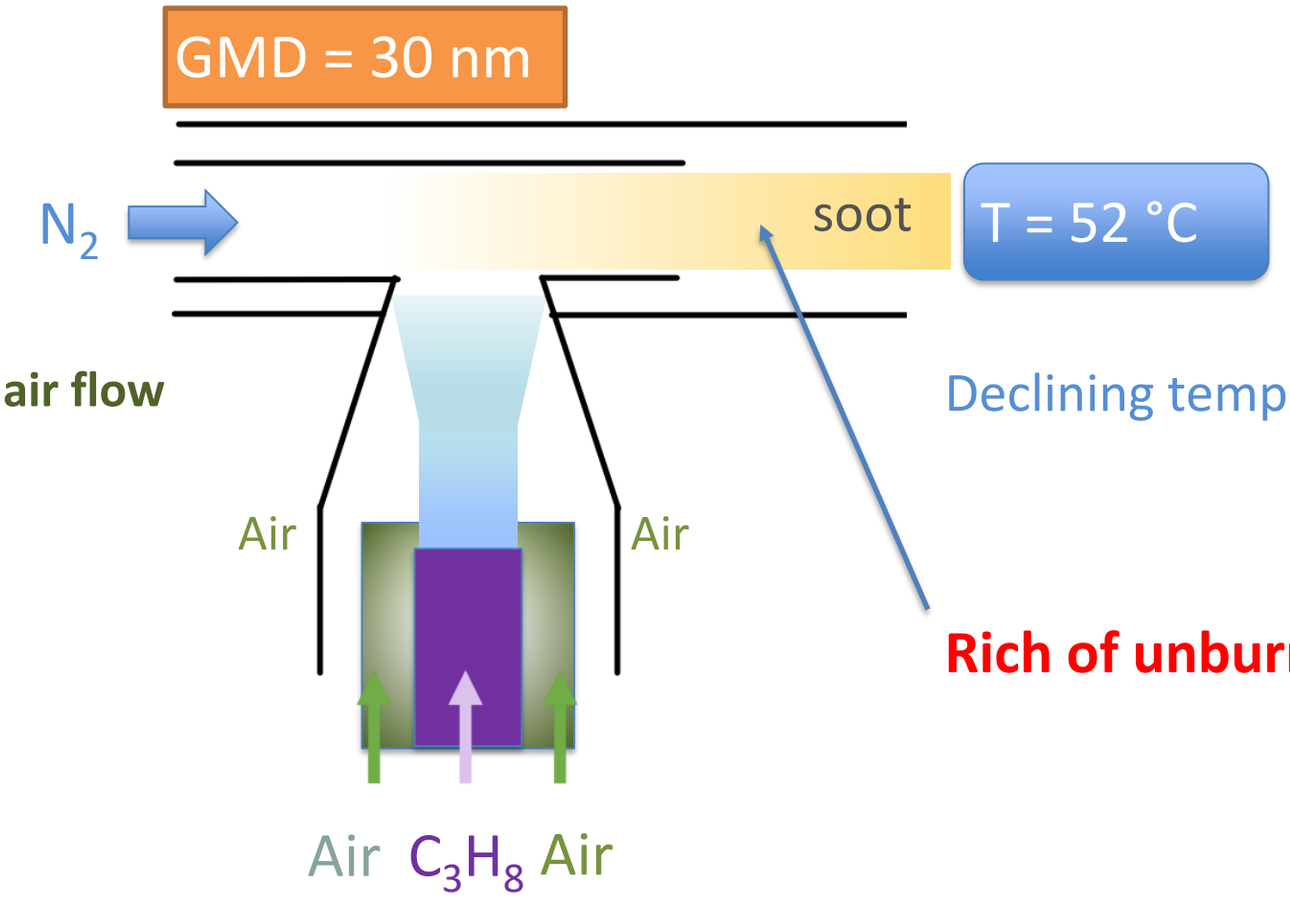


1. Understand the flame in miniCAST

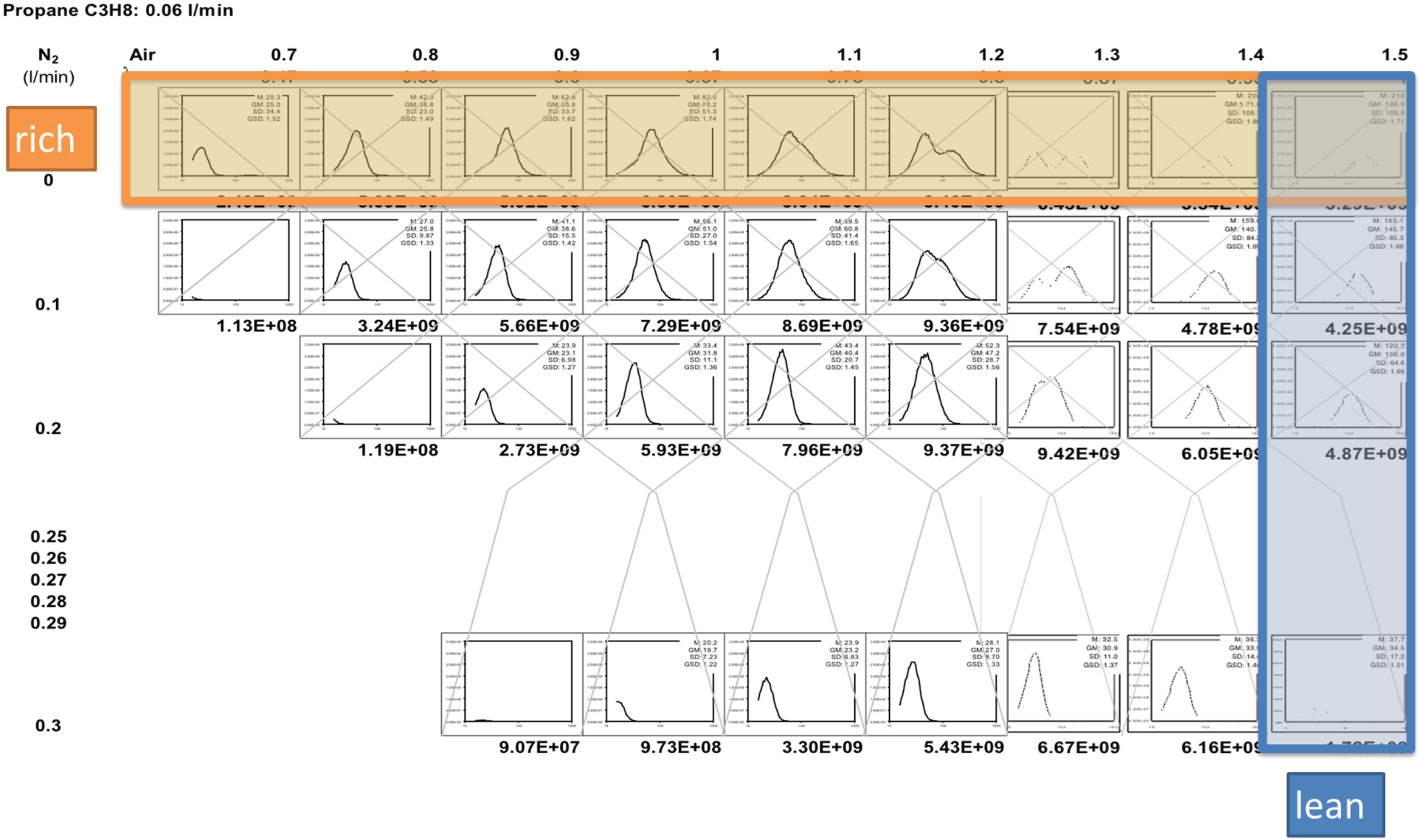
- soot from a fuel-rich flame

Quench gas with constant value set by manufacturer

Fuel-rich flame by reducing the air flow

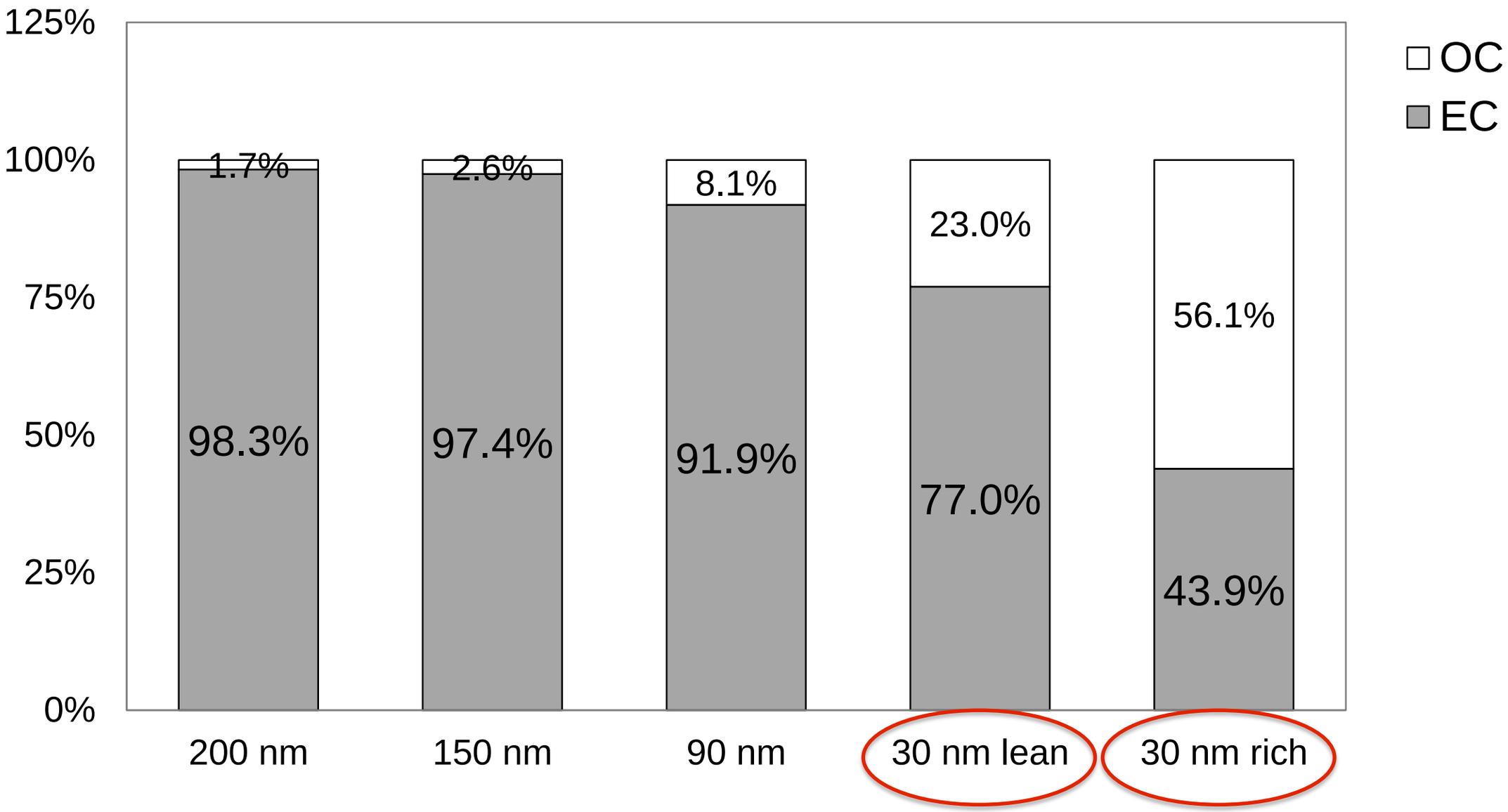


2. Map of the CAST soot



2. Map of CAST soot

- EC / OC ratio of CAST soot



Characterization of a new miniCAST with diffusion flame and premixed flame options: Generation of particles with high EC content in the size range 30 nm to 200 nm

Michaela N. Ess and Konstantina Vasilatou

Federal Institute of Metrology METAS, Bern-Wabern, Switzerland

AEROSOL SCIENCE AND TECHNOLOGY
2019, VOL. 53, NO. 1, 29–44
https://doi.org/10.1080/02786826.2018.1536818

Diffusion flame

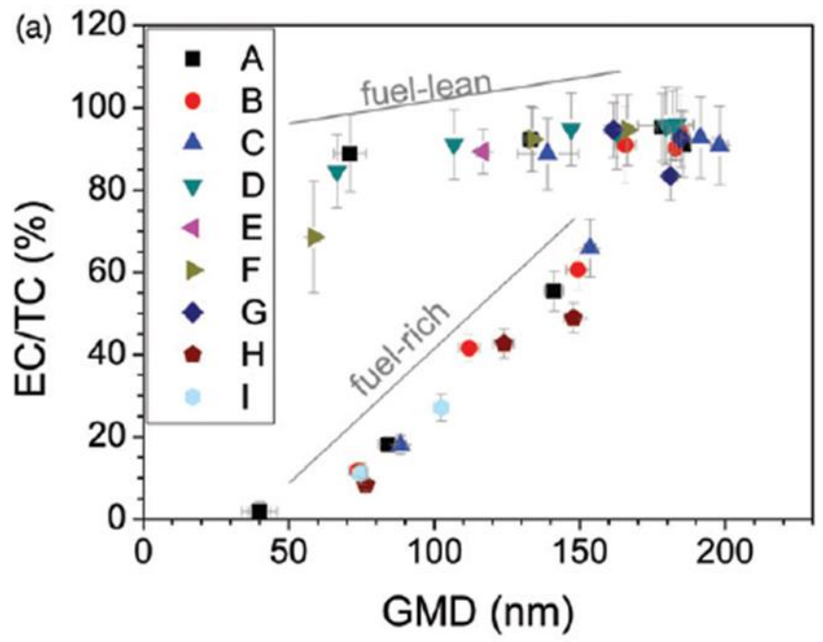


Figure 3. Correlation of (a) EC/TC ratio and (b) *AAE* with GMD of t
fusion flames. The gas flow rates of each series A–I are summariz
be found in Table S1.

Premixed flame

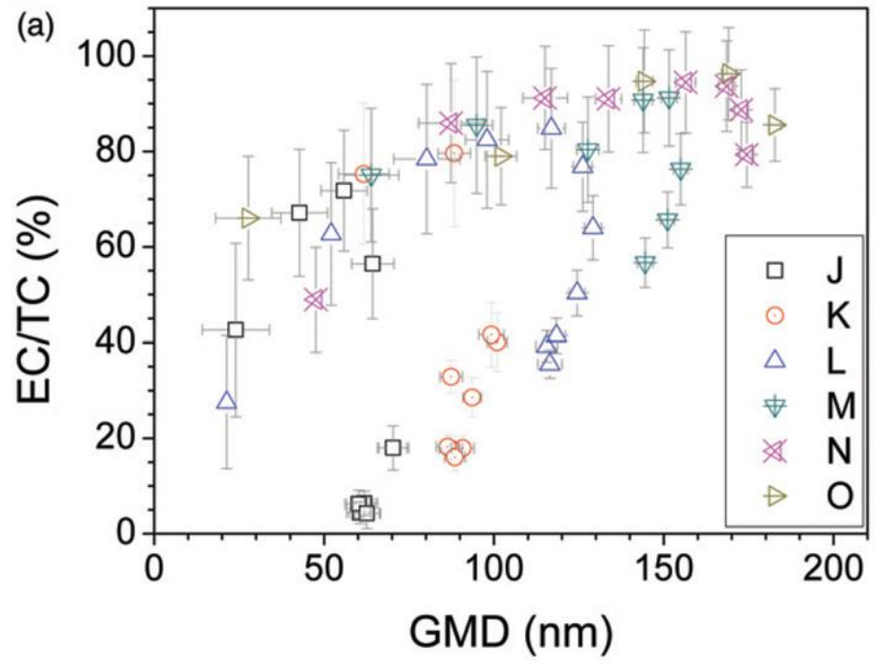


Figure 5. Correlation of (a) EC/TC ratio and (b) *AAE* with GMD of
flames. The gas flow rates of each series are summarized in Table 2;
Table S2.

5301 C (commercial type)
5201 BC (proto type)

EMPIR BLACK CARBON

EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

METAS

Characterization of a new miniCAST with diffusion flame and premixed flame options: Generation of particles with high EC content in the size range 30 nm to 200 nm

Michaela N. Ess and Konstantina Vasilatou

Federal Institute of Metrology METAS, Bern-Wabern, Switzerland

AEROSOL SCIENCE AND TECHNOLOGY
2019, VOL. 53, NO. 1, 29–44
https://doi.org/10.1080/02786826.2018.1536818

Conclusions

➢ Source of BC-like particles in a broad size range even without the use of a volatile particle remover.

➢ As model aerosol for the calibration of engine exhaust CPCs and different equivalent BC measuring instruments.

➢ Support for studies of atmospheric aerosols and calibration of BC mass instruments used for regulatory measurements of engine emissions.

5301 C (commercial type)
5201 BC (proto type)

EMPIR BLACK CARBON
EMPIR EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States
METAS

Examining the Relationship Between Black Carbon and Soot in Flames and Engine Exhaust

M. Matti Maricq
Research and Advanced Engineering, Ford Motor Company, Dearborn, Michigan, USA

Instead of 7 l/min preset by JING

TABLE 1
Parameters for min-CAST flames

Flame	C_3H_8 (mL/min)	N_2 diluent (mL/min)	Air (L/min)	Dilution air (L/min)	Quench N_2 (L/min)	Temperature[1] (K)
1	60	0	1.55	20	3	1130
2	60	100	1.52	20	3	1176
3	60	200	1.47	20	3	1204
4	60	250	1.42	20	3	1200
5	60	300	1.36	20	3	1175

Device: miniCAST 5201C

Incorrect operation!
Quench gas flow of 7 L/min preset by JING was changed to 3 L/min by author.

Causing:
- insufficient quenching of the flame
- insufficient dilution of exhaust gases in the very first moment of quenching followed by excessive condensation of OC on particles
- insufficient stabilization of the soot

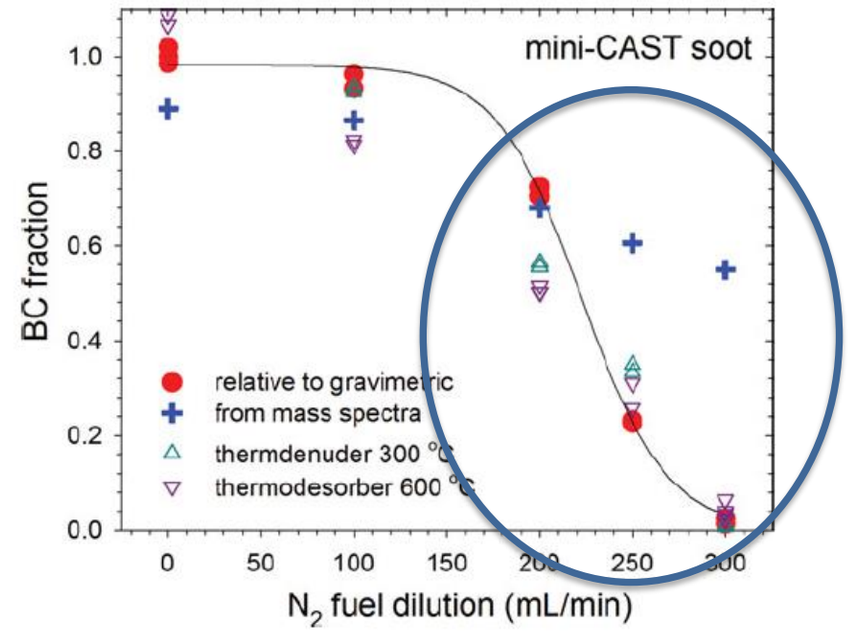


FIG. 3. BC content of mini-CAST soot versus N_2 fuel dilution.

Examining the Relationship Between Black Carbon and Soot in Flames and Engine Exhaust

M. Matti Maricq
Research and Advanced Engineering, Ford Motor Company, Dearborn, Michigan, USA

Von: [redacted]@nrc-cnrc.gc.ca]
Gesendet: Donnerstag, 8. Januar 2015 17:11
An: JING CAST
Cc: [redacted]
Betreff: RE: Question regarding 5201 burners

Hi Lianpeng;

Thank you for your response and recommendation. However, we want to repeat some tests that have been done in the past so we need the quench gas flow rate to be 3 l/min to be able to do the tests at exact same conditions. I appreciate if you let us know how to change the settings so we can set the quench gas flow rate to 3 l/min.

From: JING CAST [mailto:jing@sootgenerator.com]
Sent: Thursday, January 8, 2015 2:32 AM
To: [redacted]
Cc: [redacted]
Subject: AW: Question regarding 5201 burners

Your version: the mass flow controller for the quench gas N2 has been set to 7 l/min by the manufacture, so that the quench gas flow is omni-present as soon as the main valve is switched to on. The

Characterization of Combustion Aerosol Produced by a Mini-CAST and Treated in a Catalytic Stripper

Athanasios Mamakos,[1] Imad Khalek,[1] Robert Giannelli,[2] and Matthew Spears[2]

[1]*Southwest Research Institute, San Antonio, Texas, USA*

[2]*U.S. Environmental Protection Agency, Ann Arbor, Michigan, USA*

TABLE 1

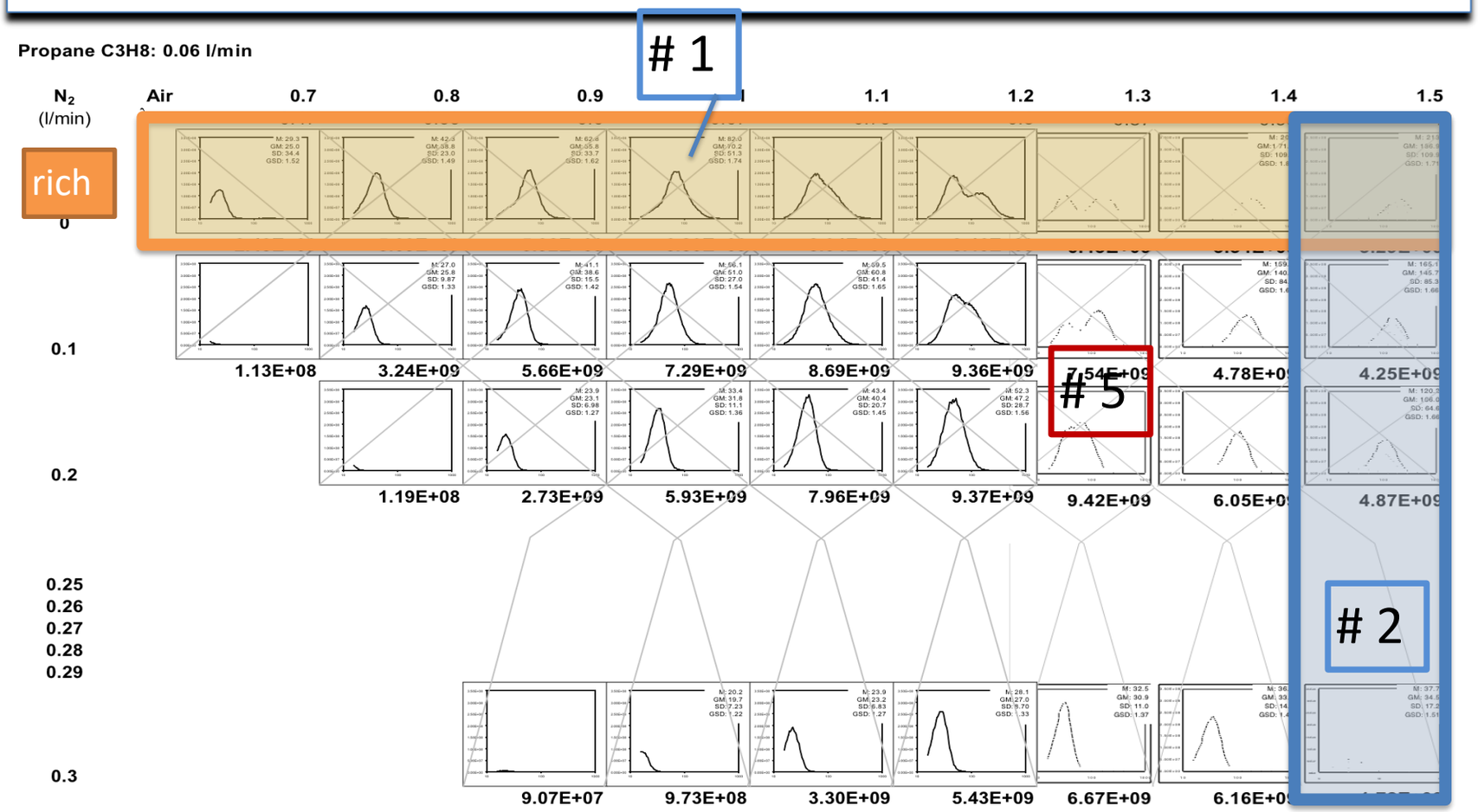
Operating conditions and properties (elemental carbon content, EC, geometric mean mobility diameter, d_g, and standard deviation, s_g; estimated primary particle size, d_{pp}, experimentally determined mass mobility exponent, D_m, and effective particle density at 85 nm, $\rho_{e@85}$) of the aerosol produced at different mini-CAST operating conditions

Point	#1	#2	#3	#4	#5	#6	#7
C_3H_8 [Nlpm]	0.06	0.06	0.06	0.07	0.08	0.08	0.08
Mix N_2 [Nlpm]	0	0.275	0.275	0	0.150	0.350	0.330
Oxidation air [Nlpm]	1	1.5	1.85	3	1.35	2	3
Overall lambda	0.67	1	1.23	1.70	0.67	1	1.5
Quench N_2 [Nlpm]	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Dilution air [Nlpm]	5	5	5	5	5	5	5
Elemental carbon content							
EC	69%	84%	92%	92%	82%	87%	90%
Size distributions							
d_g [nm]	63	81	83	85	79	78	84
s_g	1.54	1.58	1.56	1.60	1.56	1.55	1.59
Morphology							
d_{pp}	32	17	9	16	34	20	15
D_m	2.27	2.21	2.10	2.18	2.09	2.13	2.23
$\rho_{e@85}$	0.87	0.53	0.30	0.49	0.93	0.61	0.46

Aerosol Science and Technology, 47:927–936, 2013

ISSN: 0278-6826 print / 1521-7388 online
DOI: 10.1080/02786826.2013.802762

Find the operation points in the cookbook of CAST



Aerosol Science and Technology, 47:927–936, 2013

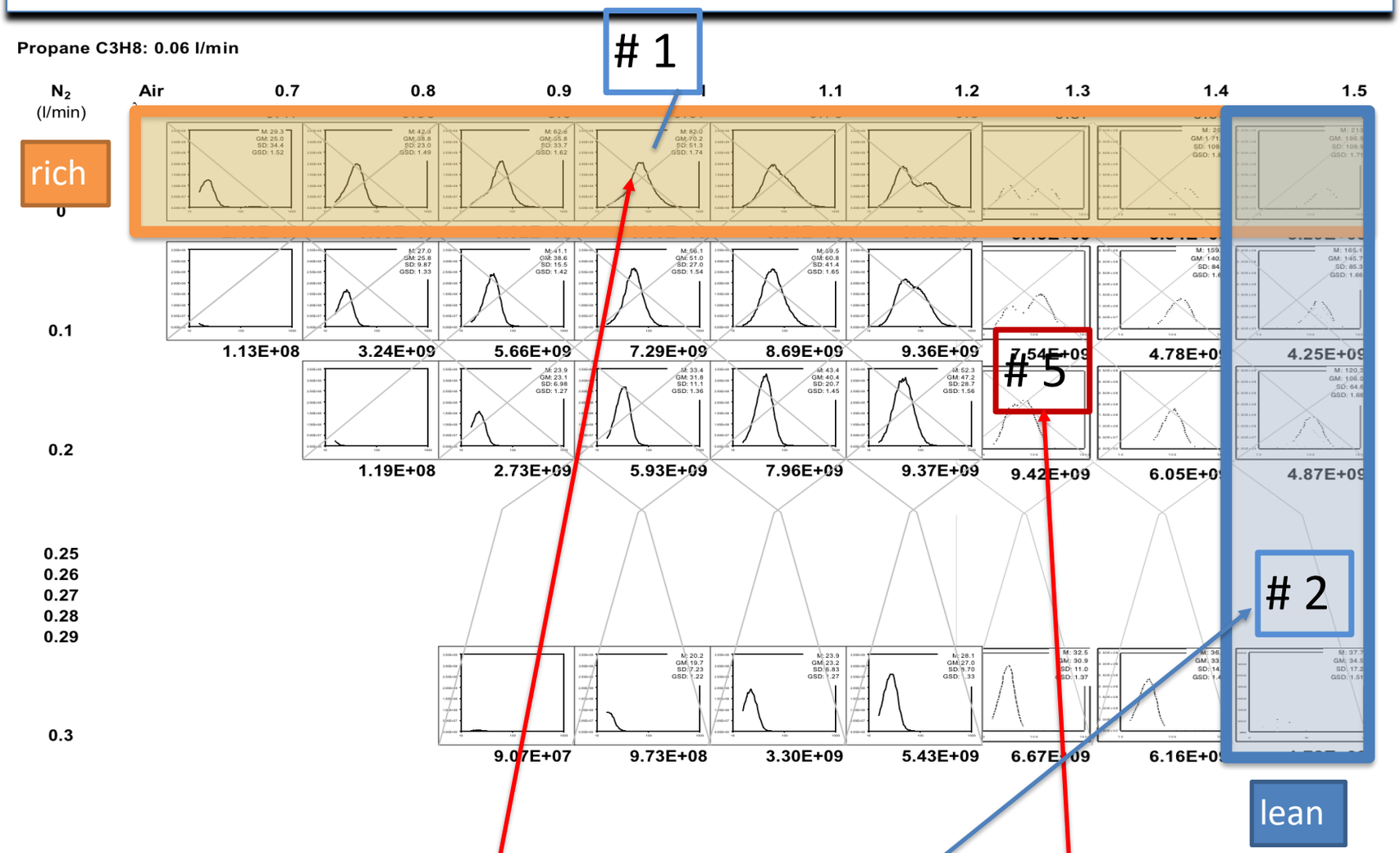
ISSN: 0278-6826 print / 1521-7388 online
DOI: 10.1080/02786826.2013.802762

Device: miniCAST 4201 + Mass flow control = miniCAST 5201C

Point	#1	#2	#3	#4	#5	#6	#7
C_3H_8 [Nlpm]	0.06	0.06	0.06	0.07	0.08	0.08	0.08
Mix N_2 [Nlpm]	0	0.275	0.275	0	0.150	0.350	0.330
Oxidation air [Nlpm]	1	1.5	1.85	3	1.35	2	3

= estimated

Find the operation points in the cookbook of CAST



Point	#1	#2	#3	#4	#5	#6	#7
EC	69%	84%	92%	92%	82%	87%	90%
Size distributions							
d_g [nm]	63	81	83	85	79	78	84
s_g	1.54	1.58	1.56	1.60	1.56	1.55	1.59
Morphology							
d_{pp}	32	17	9	16	34	20	15

Aerosol Science and Technology, 47:927–936, 2013

ISSN: 0278-6826 print / 1521-7388 online
DOI: 10.1080/02786826.2013.802762

4. Models of miniCAST generating high EC

High EC content in the size range below 30 nm needs

- High reaction temperature
- … enhenced carbonisation

4. Models of miniCAST generating high EC

- Implementation in CAST

- **Stoichiometrically sufficient oxidation air flow**
  - – quick dehydration of HC and accelaration of the soot formation
- **Lean fuel by mixing N_2 or Air into C_3H_8**
  - – both: surpression of soot formation by diluting the fuel gas.
  - – both: prevents soot particles from agglomeration
  - – air: oxidation of soot particles
- **Extended flame height**
  - – longer retention time

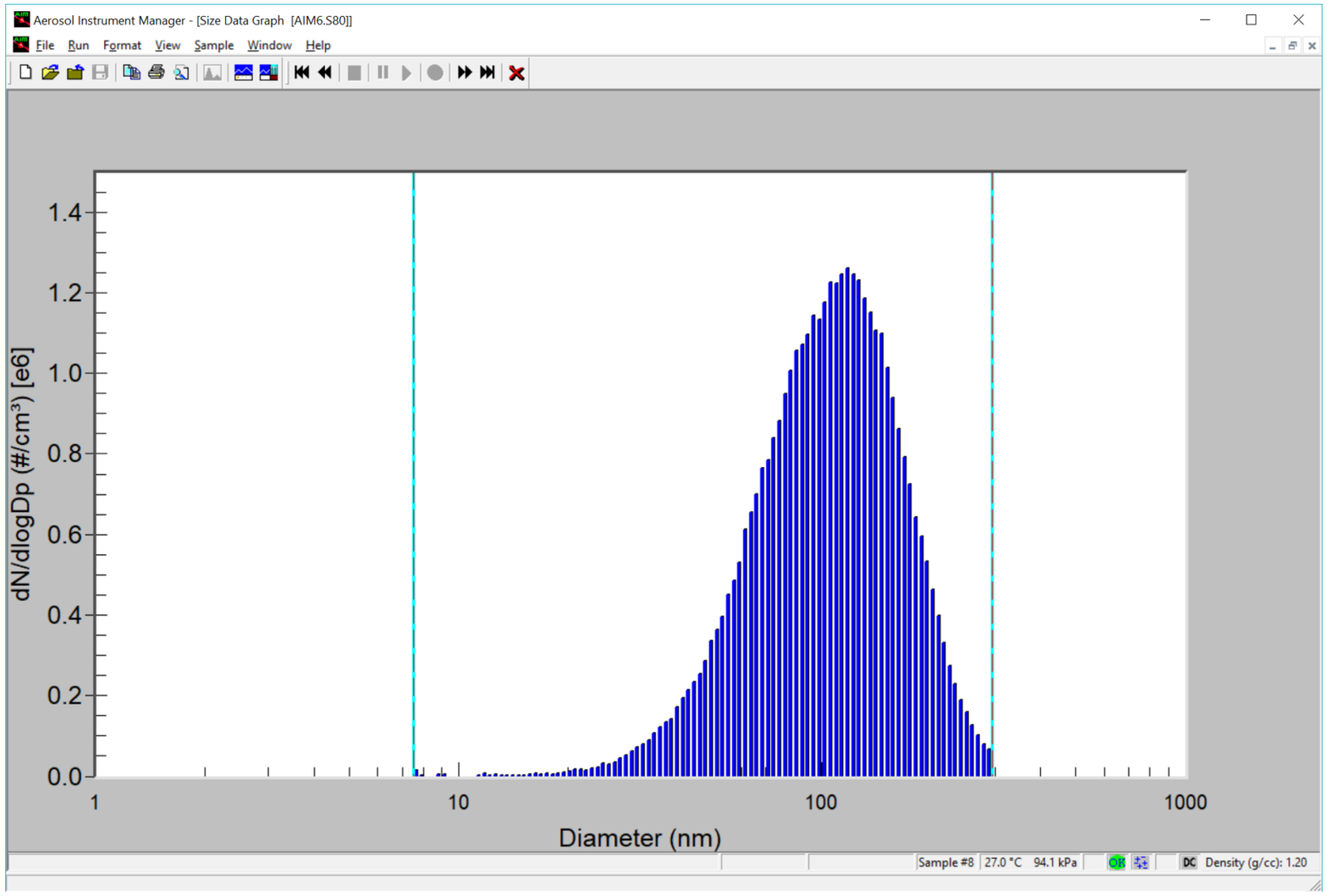
4. Models of miniCAST generating high EC

- lastest models

	6301C	5301C	5303C	5304C
Number of flame	1 flame	1 flame	3 flames	4 flames
Fuel consum. (ml/min)	25	60	160	250
Flame height (mm)	16	42.5	40.5	40.5
Fuel-lean flame	☑	☑	☑	☑
Size range [nm]	8-200	8-200	8-200	8-200

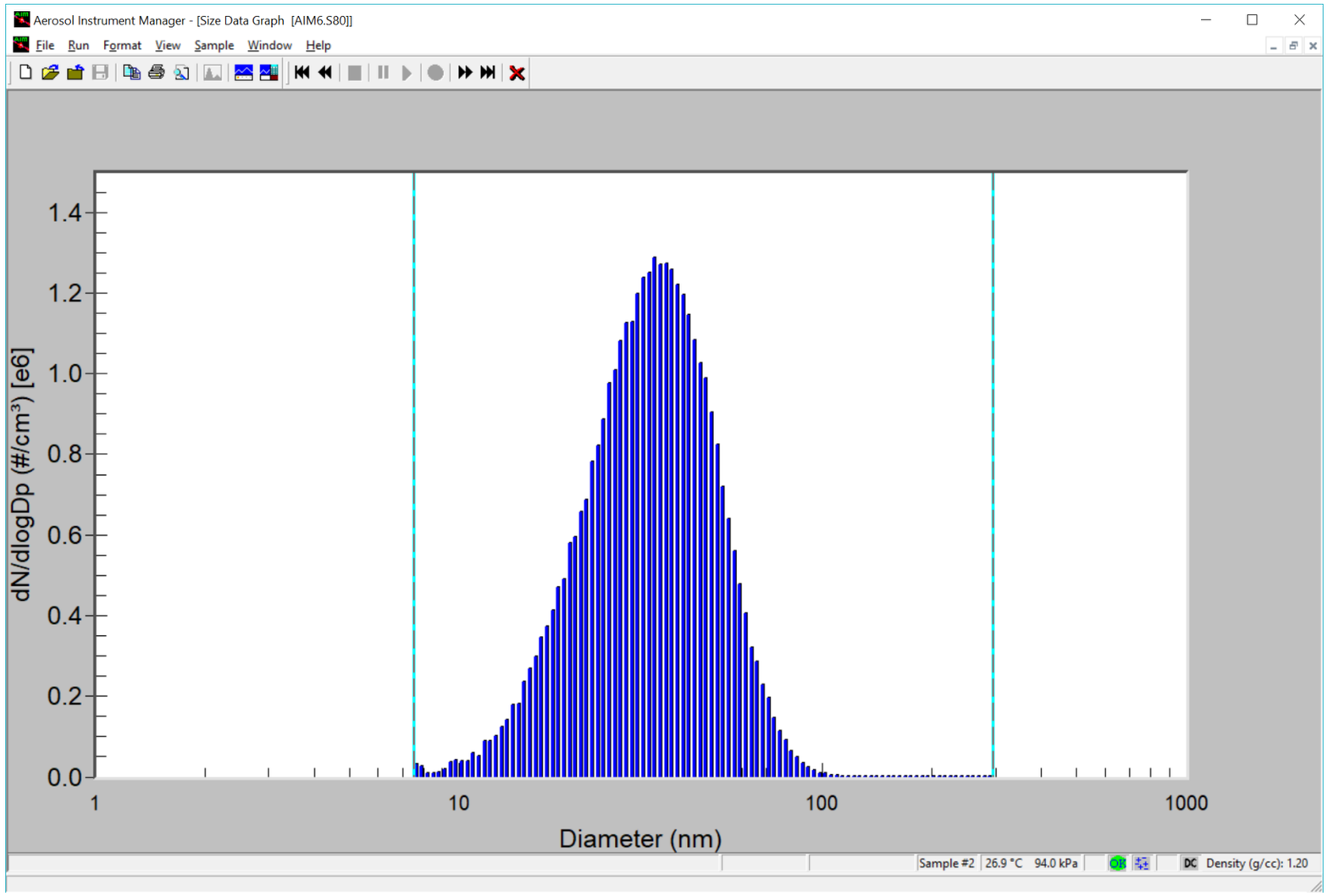
4. Models of miniCAST generating high EC

- GMD of soot particle from miniCAST 6300 and 5300



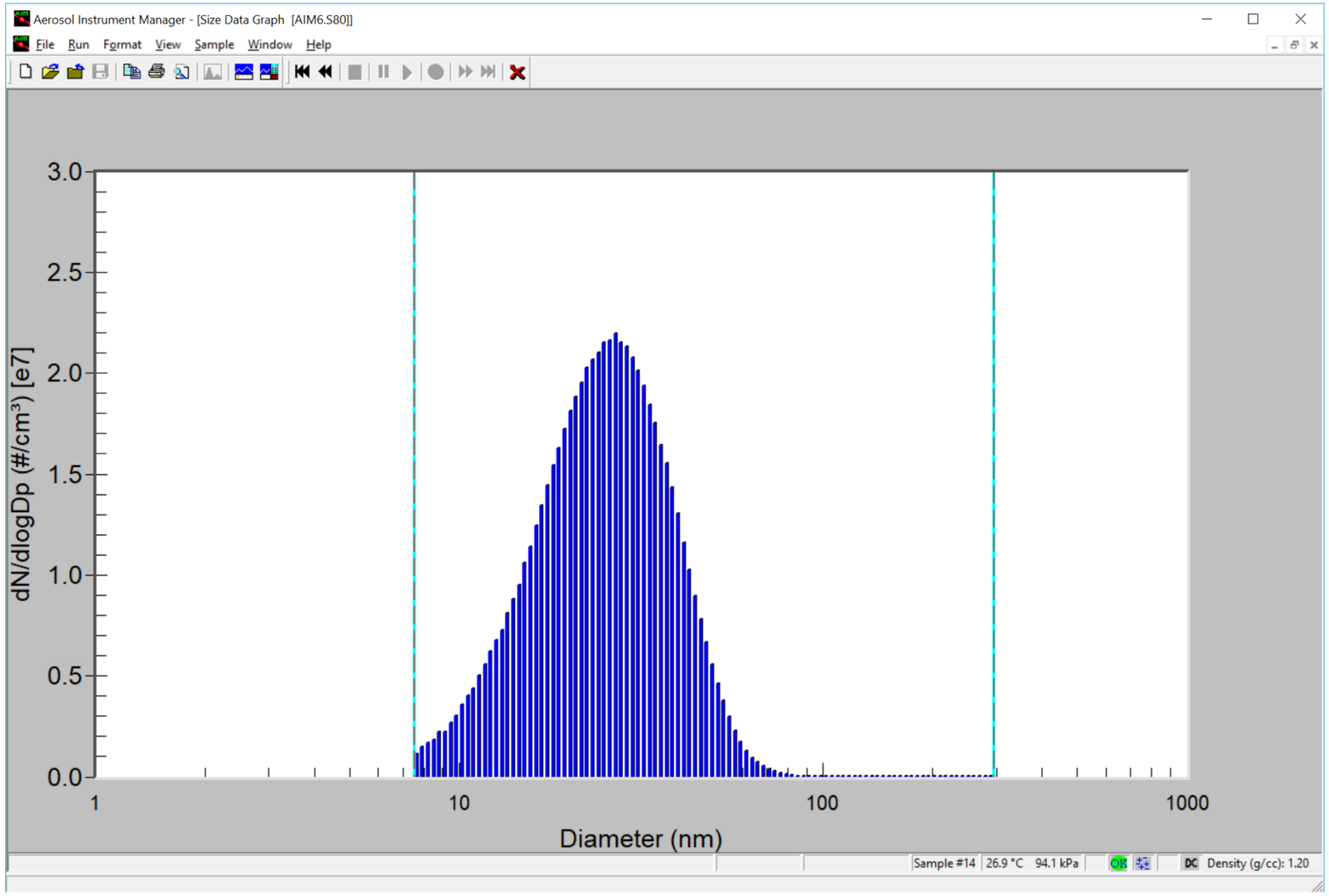
4. Models of miniCAST generating high EC

- GMD of soot particle from miniCAST 6300 and 5300



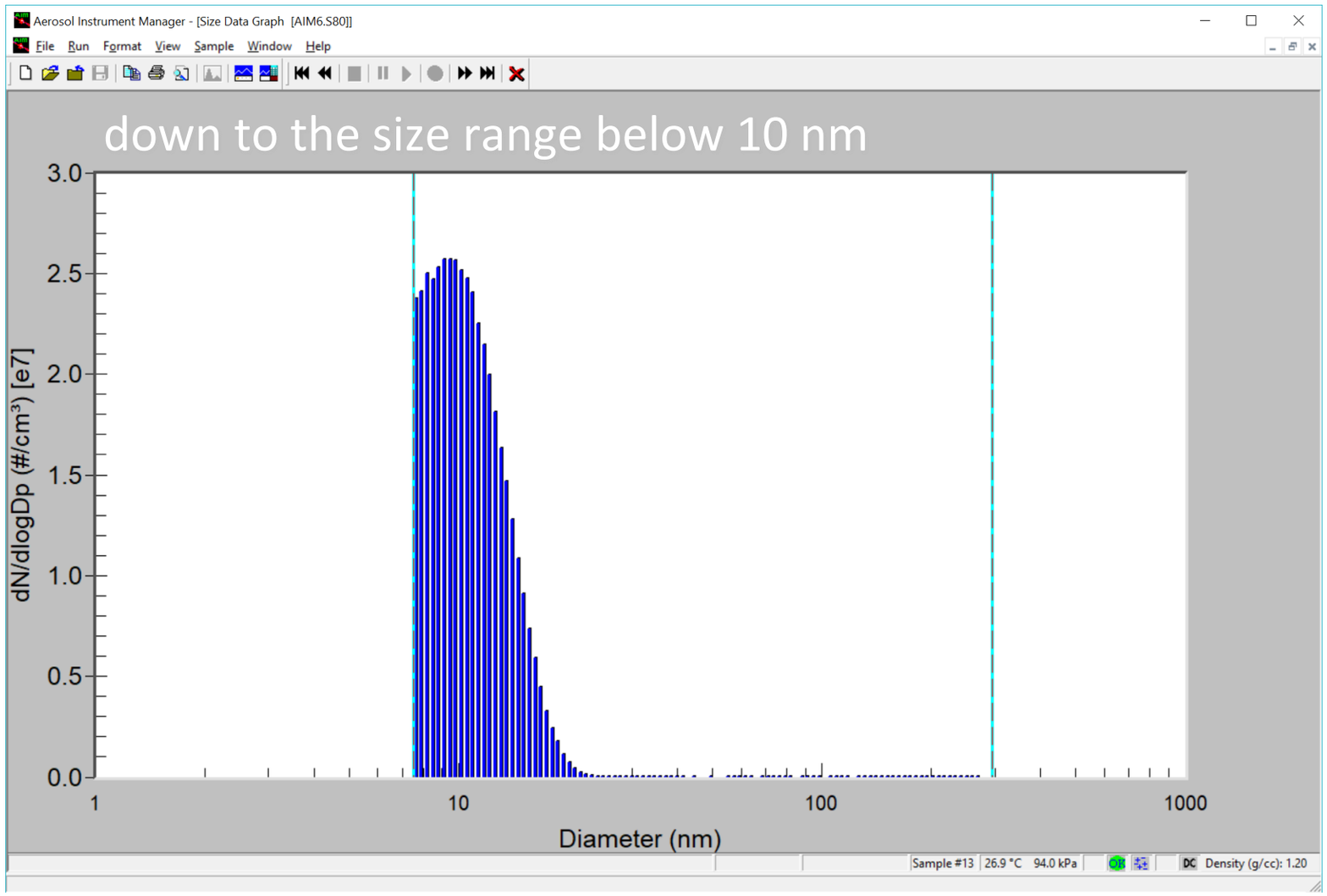
4. Models of miniCAST generating high EC

- GMD of soot particle from miniCAST 6300 and 5300



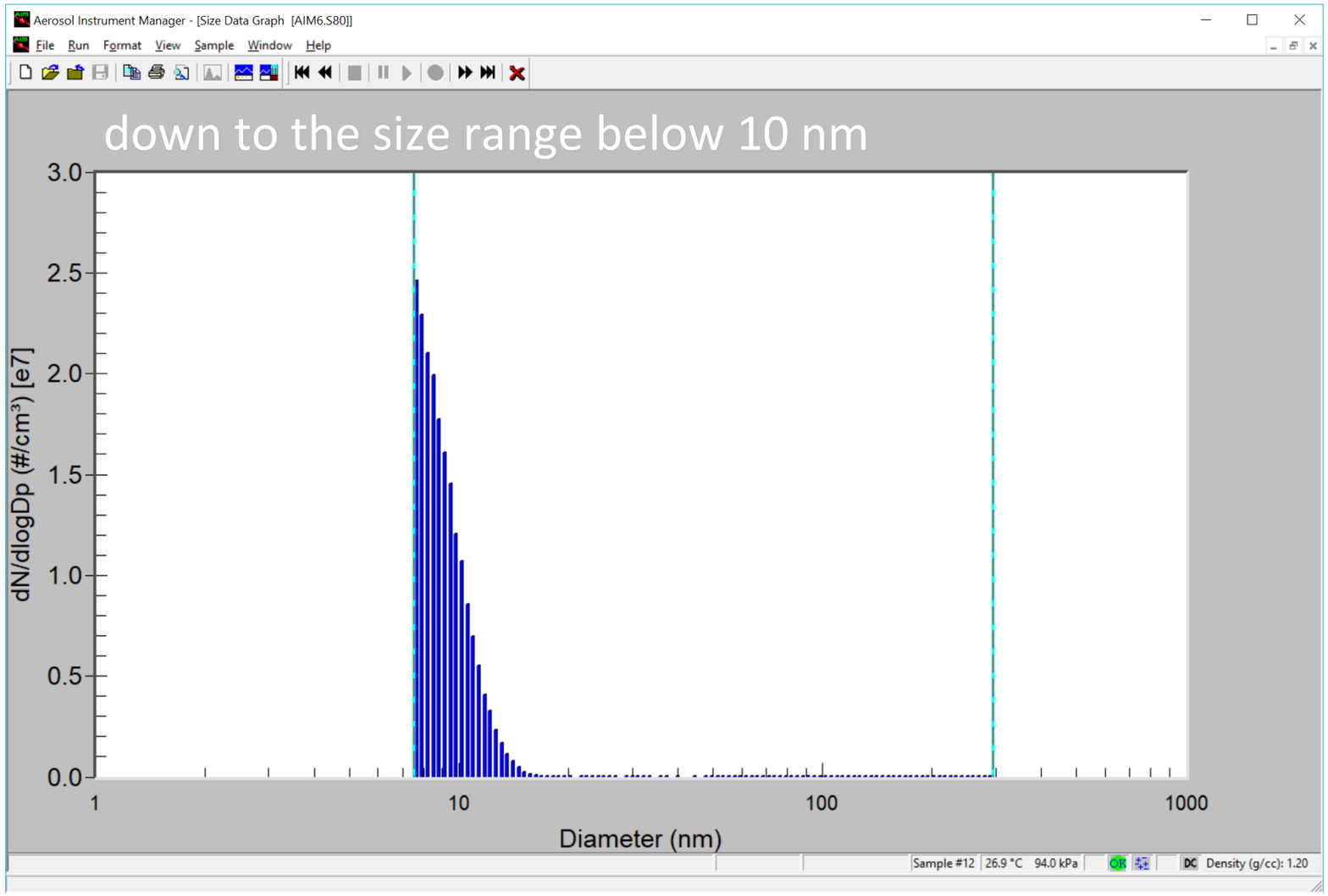
4. Models of miniCAST generating high EC

- GMD of soot particle from miniCAST 6300 and 5300



4. Models of miniCAST generating high EC

- GMD of soot particle from miniCAST 6300 and 5300



4. Models of miniCAST generating high EC

- older models

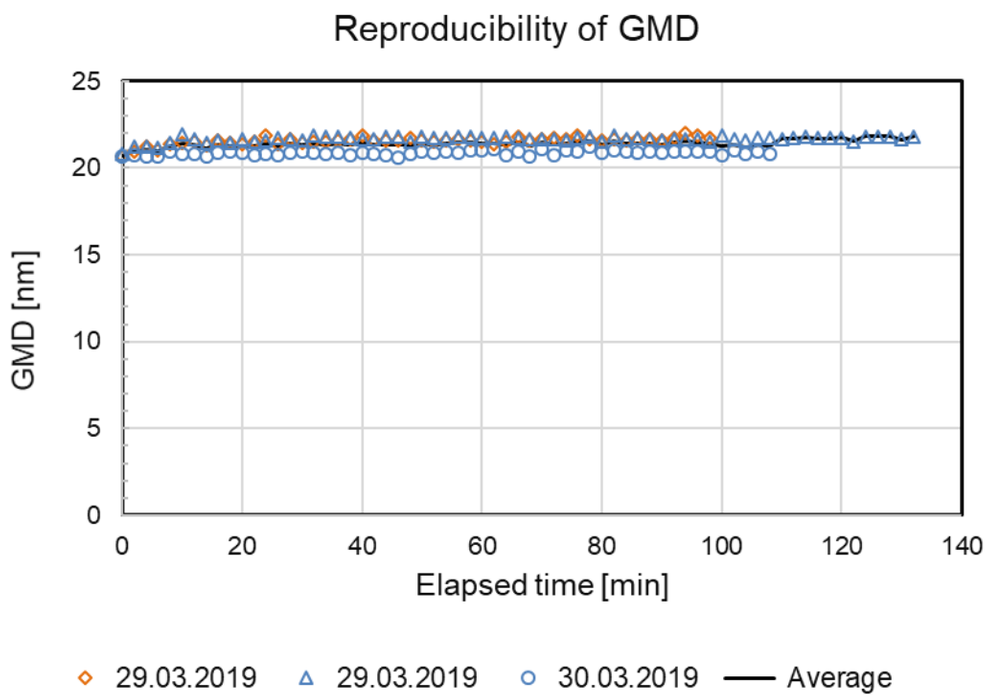
	6204C	5201C	5203C
Number of flame	1 flame	1 flame	3 flames
Fuel consum. [ml/min]	25	60	160
Flame height [mm]	16	42.5	40.5
Fuel-lean flame (N2)	☑	☑	☑
Size range [nm]	20-200	20-200	20-200

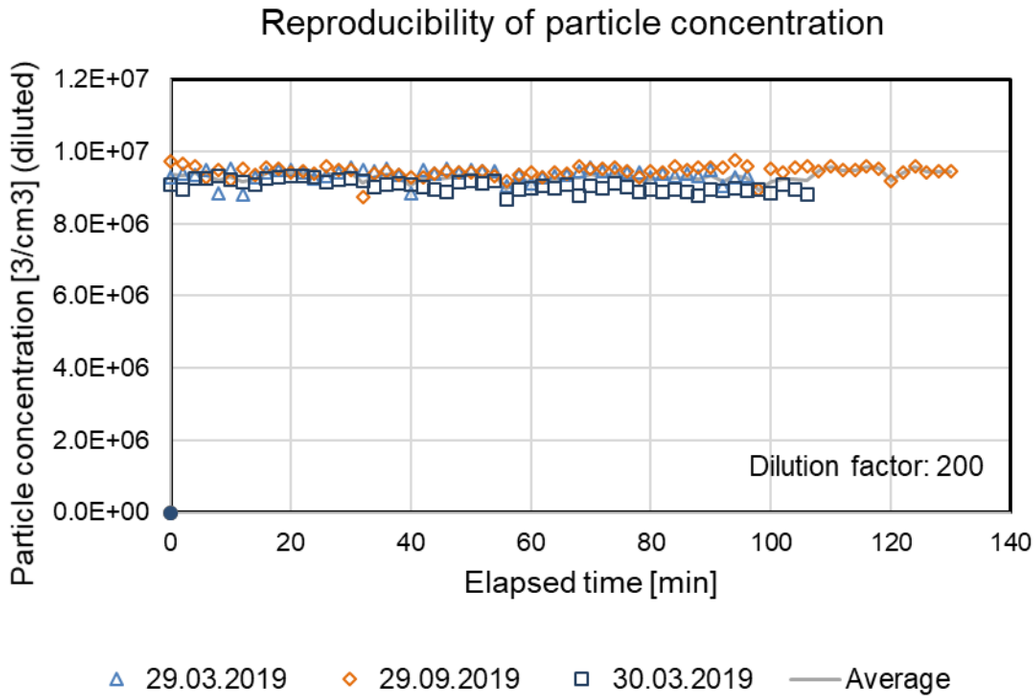
Series 6200

Series 4200

Series 5200

5. Statility and reproducibility





Relative deviation

Intraday:	GMD < 1.5 nm difference,
	Conc < 5 % difference
Day to day:	GMD < 2%,
	Conc < 10%

6. Conclutions

1. miniCAST models are able to deliver high level EC/OC ratios of soot in a wide size range, including 10 and 23 nm.
2. Use of a volatile particle remover is not compelling or unnecessary
3. Very good stability and repeatability
4. With real soot particle as standard we are forearmed for any future upcoming soot related topics that are not yet recognized as relevant nowadays.
5. miniCAST models all together cover a wide range of soot mass output that meets different demands of particle measurement.

Thank you for your attention!

Q&A