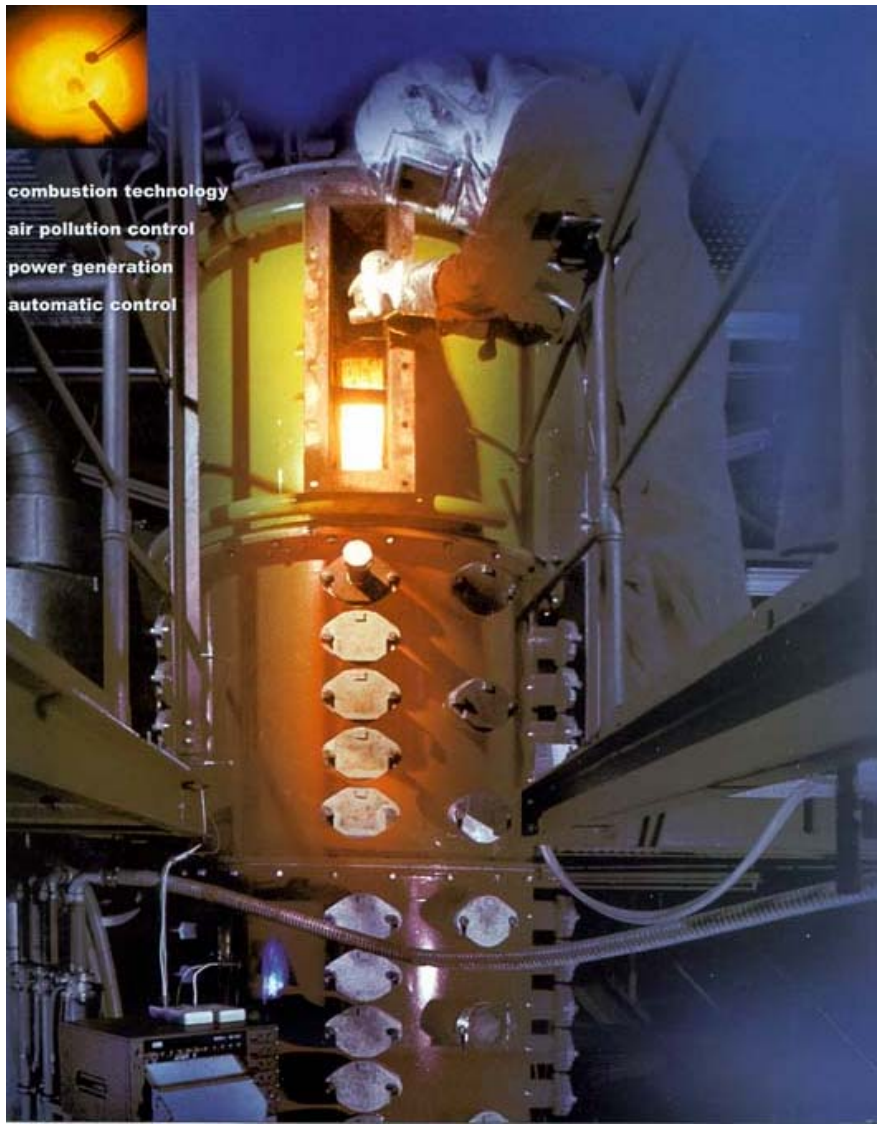
Institut für Verfahrenstechnik und Dampfkesselwesen
Institute of Process Engineering and Power Plant Technology
Prof. Dr. techn. G. Scheffknecht
Universität Stuttgart

// QUOVADIS

Workshop Rome

24 October 2007//



IVD Uni-Stuttgart

Jörg Maier
maier@ivd.uni-stuttgart.de

Content of Presentation

- Role of IVD, SRF Utilisation
- Standard Methods
- Advanced Methods
- Conclusions

Role of IVD, Waste to Energy

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Standard fuel analysis

SRF

Proximate analysis

Ultimate analysis

Size distribution

Major & minor elements, ash fusion and melting,

etc.

Lab-scale tests with advanced methods

SRF

Aerodynamic properties

Kinetic parameters for simulation purposes

Intermediate char properties

Residence time for complete combustion

etc.

Semi-technical and pilot scale combustion tests

Pulverised fuel | Fluidised bed | Grate firing | others

Full scale test

Combustion Test Facility (500kW)

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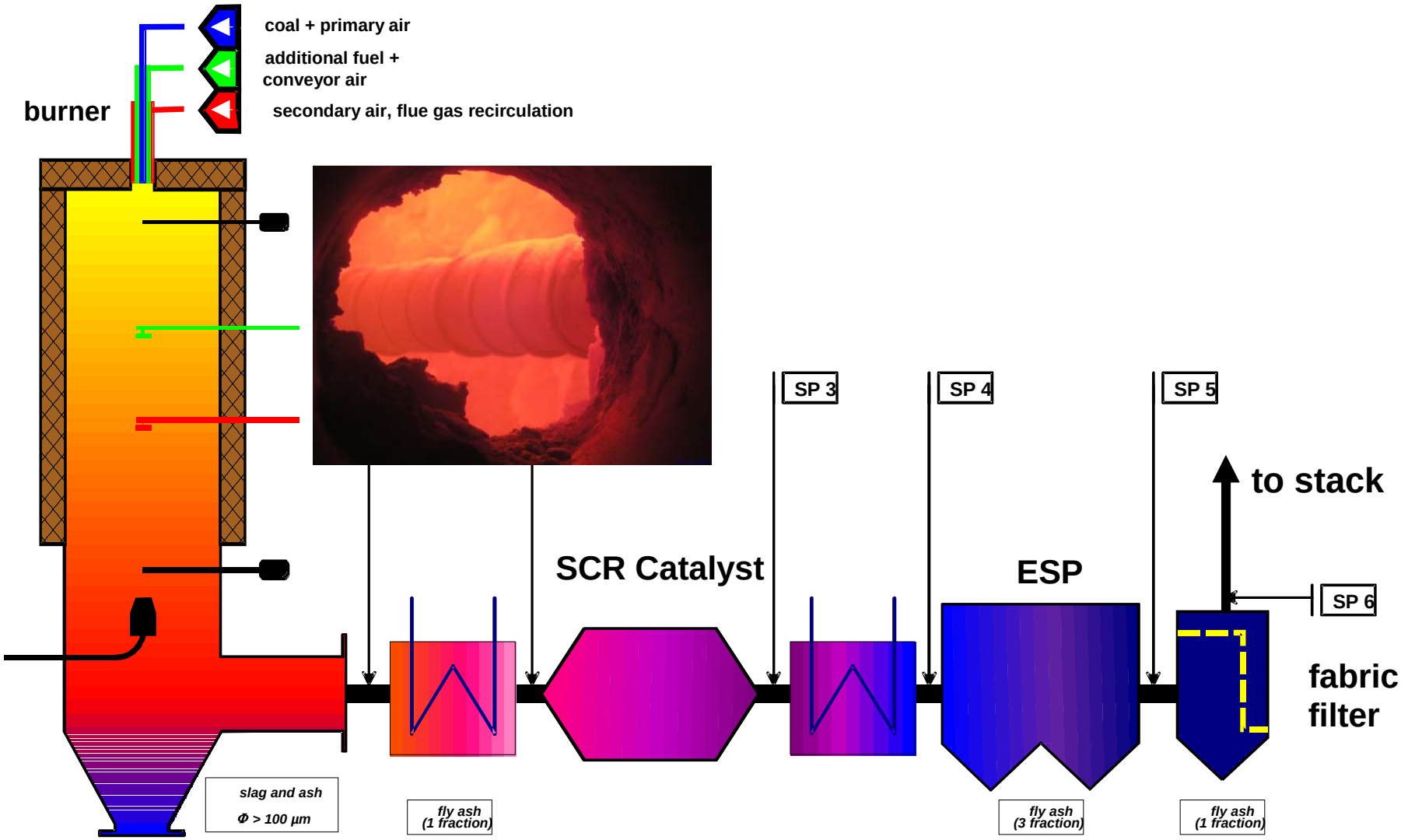

Characterisation of SRF:

Physical Parameters

Partners WP5 (Physical Parameters) and their role

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University Stuttgart, (IVD), Leader WP 5

Task 5.1ruggedness testing of TS

- volatile matter, ash content, ash melting, particle size

Task 5.2/5.3 organizing all necessary arrangements, data transfers required by intercomparision and validation tests

Research Institute of Combustion (IRC/CNR)

Task 5.1: bridging properties

Swedish University of Agricultural Sciences (SLU)

Task 5.1: calorific value, moisture content, durability

Technical Research Center of Finland (VTT)

Task 5.1: Bulk density, density of pellets and briquettes

>> All partners took part in the validation tests too

Materials received for the RUGGEDNESS TEST

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IVD received different samples prepared by JRC Geel

	Description	1 mm, 20 g	1 mm, 200 g	6 mm, 20 g	6 mm, 200 g
QR-A	shredded tyre*	14	2	14	2
QR-A2	shredded tyre**	14	2	14	2
QR-B	demolition wood	14	2	14	2
QR-C	dried sludge (paper, sewage?)	14	2		
QR-E	paper/plastic mixture	14	2	14	2
QV-A3	shredded tyre**	10 x 5.0 g			
QV-B	demolition wood	10 x 5.0 g			
QV-C	dried sludge (paper, sewage?)	10 x 5.0g			
QV-D	dried SBS	14 x 5.0 g			
QV-E2	paper/plastic fluff	14 x 5.0 g			

* with less wires & textiles content

** with more wires & textiles content

In addition, some materials were received from Remondis

IVD Work content

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- Homogeneous Test of Samples

Ruggedness Test on the TS:

- Ash Content Determination Procedure;
- Volatile Content Determination Procedure; and
- The Procedure for Ash Melting Behavior

- Remarks & Recommendations TC 343 before the upgrade of TS to EN

Ruggedness Test:-

Ash Content Determination

Ruggedness Test: Ash Content Determination

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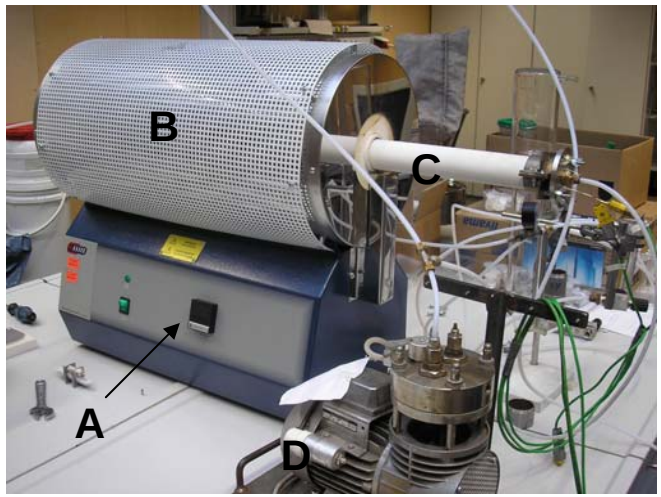
Technical Specification	
Oven Air change rate	5-10 air changes/min
Heating rate	5 K/min
Sample bottom area Loading	≤ 0.1 g/cm²

1 g sample heated to 250 °C (5 K/min), it stays at this temp. for 1 hr; temperature further raised to 550 °C (5 K/min), sample stays at this temperature for 2 hrs.



SRF QR-A shredded tyre

110 mm

1 g sample loading = 0.05 g/cm2 bottom area.

Results: Temperature Profile

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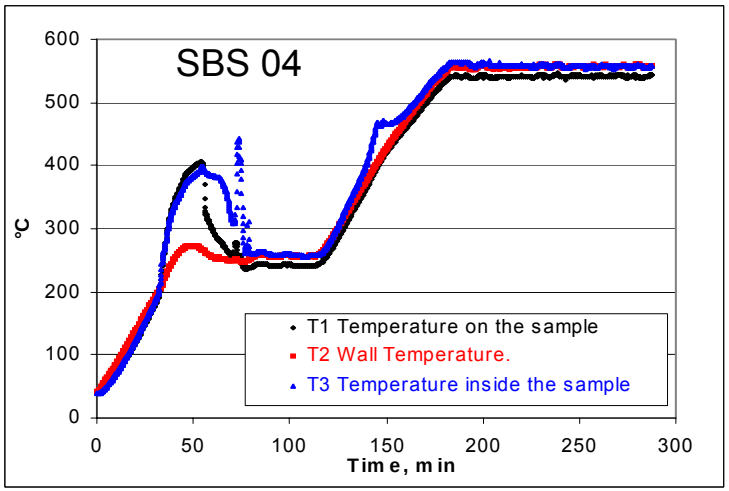
A.



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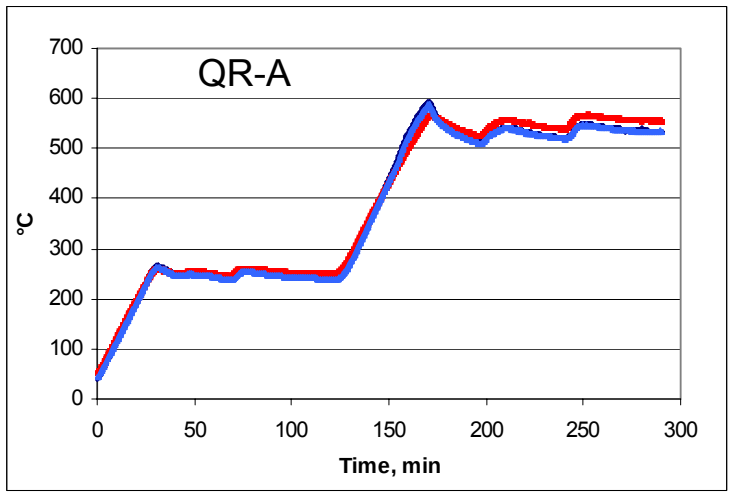

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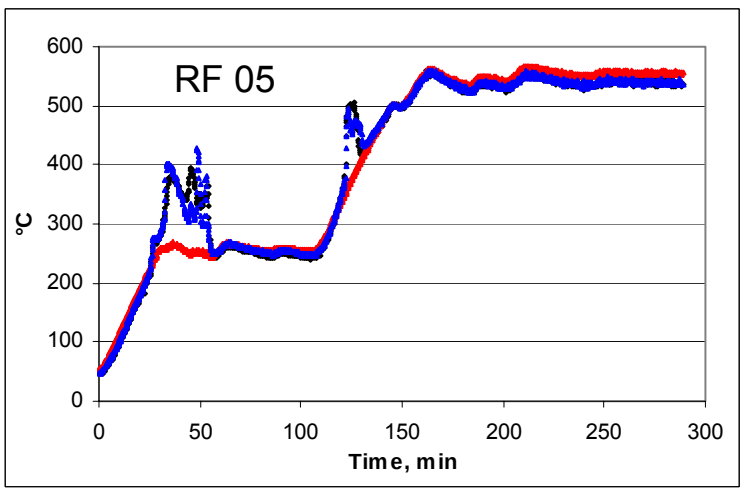

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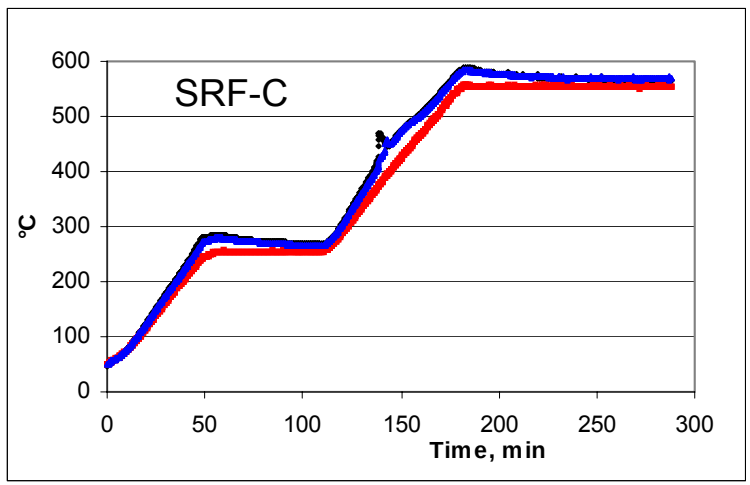

Raw Fuels and Ash

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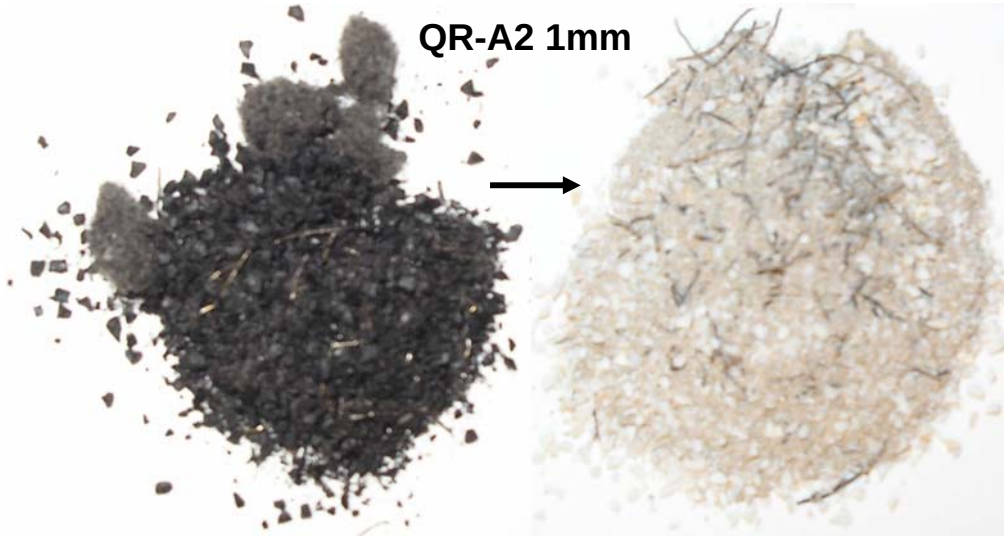

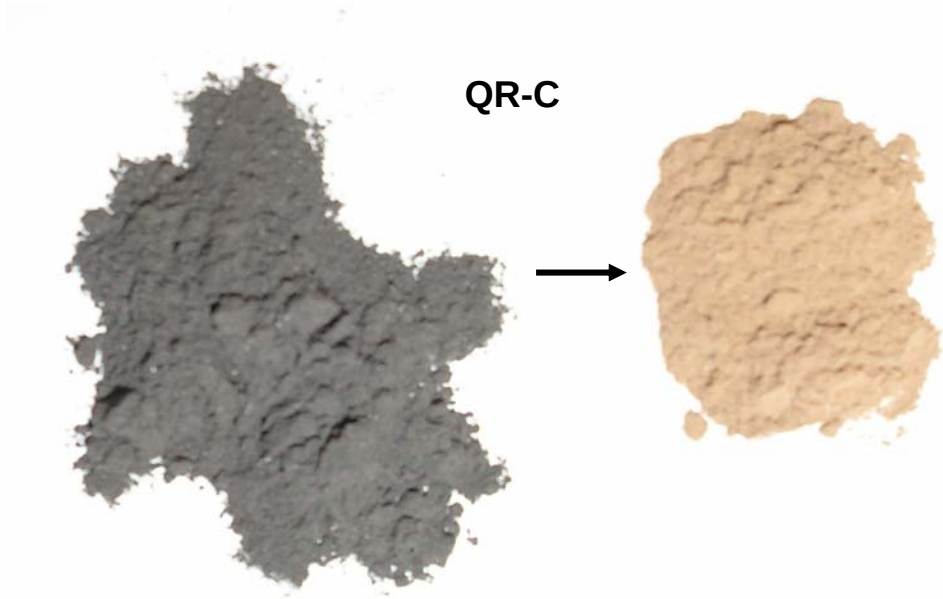

Observations:

- Physical observation of the resulting ashes revealed **no sign of incomplete incineration**. i.e.
  - No signs of soot at visual inspections.
- At visual inspections, **incineration were complete** for all the different types of SRF samples.

Remarks / Recommendations to the TS 15403

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[√] **Ash Content Determination Procedure**:

- The procedure led to a complete incineration of SRF,
- No foreseen problems with the method,

We therefore propose no major changes to the drafted TS 15403

Ruggedness Test:-

Determination of Volatile Matter

Determination of Volatile Matter

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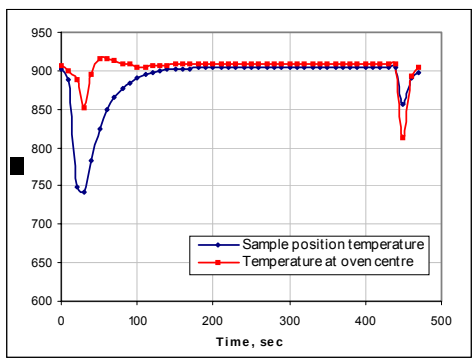
Oven used: **Muffle oven**

- Maintains a uniform and a constant temperature.
- Dimensions: 33 x 22 x 20 cm.
- Two thermocouples are placed in the oven; one at sample position and the other in the middle of the oven.
- Figure is a Silica crucible and lid resting on a ring of heat-resistant steal wire for single determination
- crucible is loaded with 1±0.1 g test portion
- set-up is transferred into the heated oven at 900±10 °C for 420±10 sec.

Technical Specification	
Test portion	1±0.1 g
Oven Temperature	**900±10 °C**
Duration	**420±10 s**



Summary *Volatile Matter*

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Sample Nr.	Size	Mean %	Std %	Max. Range %
QR-A	< 6 mm	54,50	3,01	10,98
QR-A2	< 1 mm	54,56	1,06	3,21
QR-A2	< 6 mm	54,87	3,31	13,05
QR-B	< 1 mm	72,72	0,36	1,21
QR-B	< 6 mm	73,35	2,02	8,09
QR-C		26,91	0,19	0,63
QR-E	< 1 mm	78,99	0,52	1,63

- Deviation increases in proportion to the sample sizes
- More homogeneous samples are with less deviations; results are reproducible.
- It is difficult to have a representative test portions (1± 0.1 g) in samples like QR-A2, which are mixture of rubber, textile and metal wire contents.

Remarks / Recommendations to the TS 15402

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[√] **Content of Volatile Matter:**

SRF fractions, < 1 mm, results were repeatable & reproducible. This is with the exception of the critical samples e.g. QR-A2.

Sample size were found to be a critical parameter affecting the precision of the method. Larger particle sizes increase the uncertainties in the results.

The precision of the method is also affected by the degree of sample homogeneity.

No foreseen problems with the procedure.
As such we propose no major changes to the drafted TS 15402.

Volatile Matter Determination:- Instrument Analysis Method (e.g. TGA)

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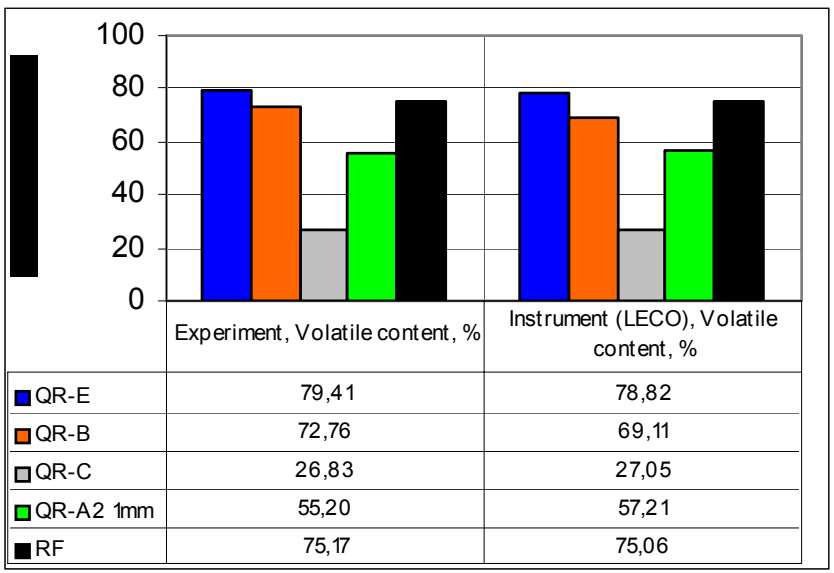
- A fuel sample (1-2 g) is introduced in the TGA analyzer. Usually, these devices can be programmed for automatic operation, following step 1 through 3:

- **Step 1**: Under reducing atmosphere (N2), the temperature is increased to 105±1°C (sample drying). If the mass deviation is below 0.1%, the procedure continued with step 2.

- **Step 2**: Under reducing atmosphere (N2), the furnace temperature is raised to a 900 °C. Once this set temperature is reached, it stayed for 7 minutes before continuing with step 3.

- **Step 3**: Under reducing atmosphere (N2), the furnace cools down to 105°C. The volatile matter is calculated automatically by the analyzer.



	Experiment, Volatile content, %	Instrument (LECO), Volatile content, %
QR-E	79,41	78,82
QR-B	72,76	69,11
QR-C	26,83	27,05
QR-A2 1mm	55,20	57,21
RF	75,17	75,06

Remark / Recommendation:

- Results from the experimental and instrumental analysis proved to be comparable. That is, there were no significant deviations between the results from the two methods.
- There were also no technical challenges during the experiment.

We therefore recommend a TS that well address a fully automated approach to determine the Volatile matter.

Ruggedness Test:-

Determination of Ash Melting Behaviour

Ash Melting Behaviour

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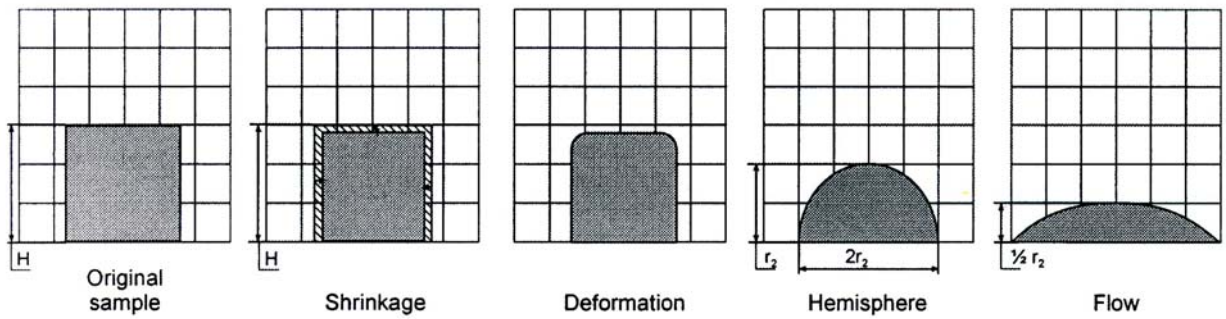
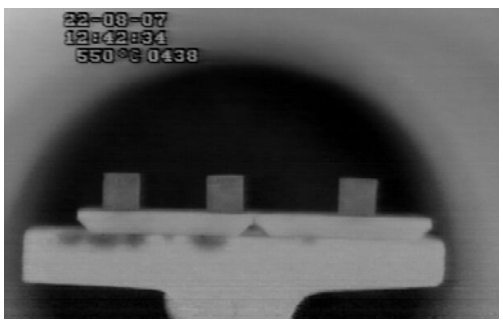
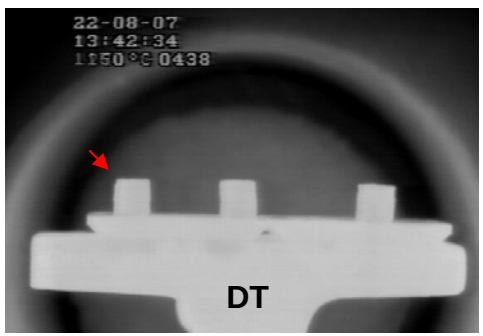
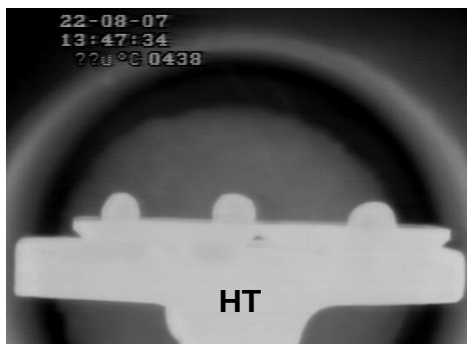
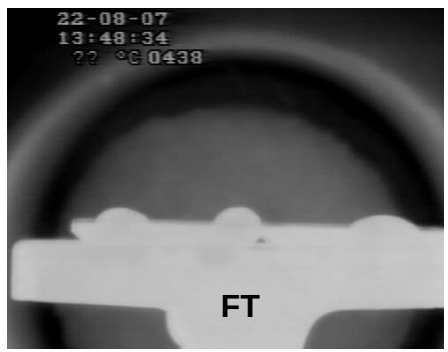
	TS	Raggedness Test IVD
Dimensions of sample	cylinder; h=3 to 5 mm; with height = diameter	Cylinder: h = 5 mm; d = 5 mm
Furnace atmosphere	oxidizing or reducing atmosphere	Oxidizing (CO_2) atm
Furnace Temperature	≥ 1500 °C	1500 °C max.
Heating rate	5 K/min -10 K/min	10 K/min (heating rate)











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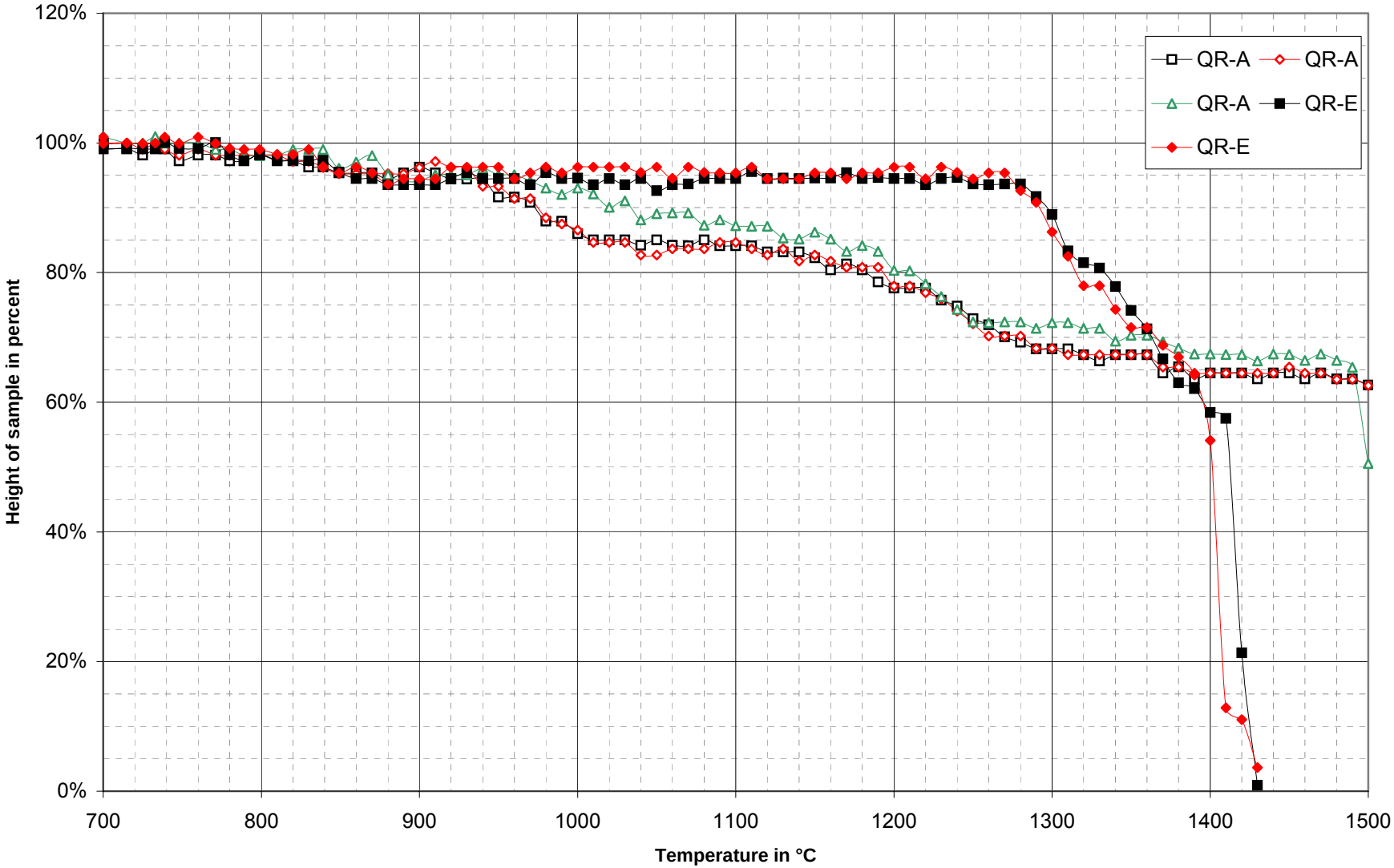
Ash Melting Behaviour



Summary: Remarks/Recommendations

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[√] Ash Content Determination TS15403:

- The procedure led to a complete incineration of SRF.
- No foreseen problems with the method.
- We therefore propose no major changes in the draft.

[√] Content of Volatile Matter TS15402:

- No foreseen problems with the procedure, as such we propose no major changes to the drafted TS.

[√] Ash Melting Behaviour TS 15404:

- No major changes are recommended to this TS, however, there is a challenge concerning the determination of the shrinkage temperature, 95 % of the original sample area.

Advanced Methods to characterise Physical Properties of SRF/ and solid Biomass

Investigation on the residence time of Rofire III pellets

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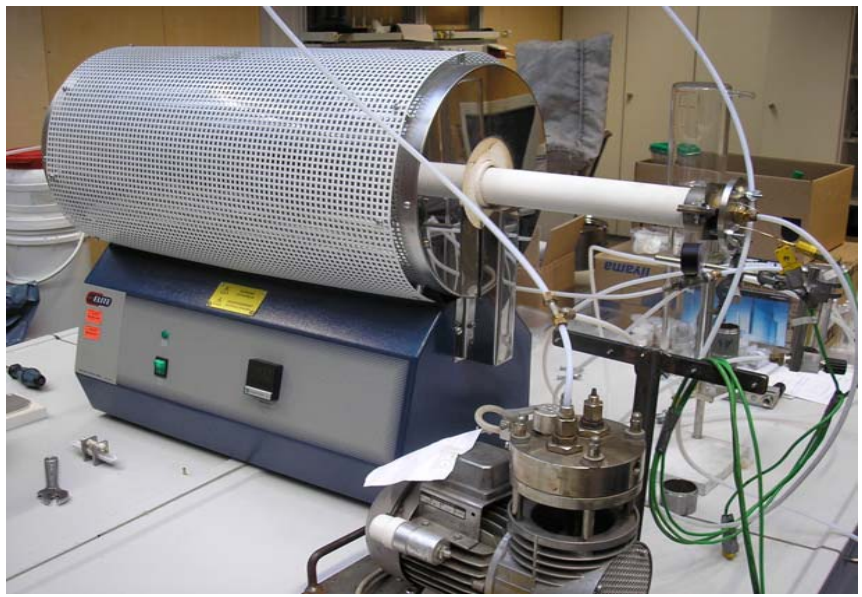
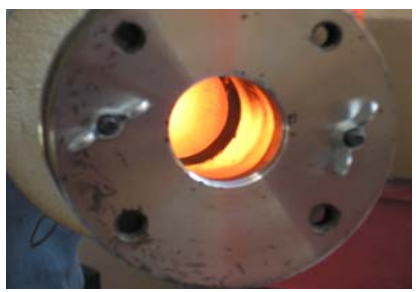
- The **objective** is to study the residence time required to completely combust particles/pellets and to receive intermediate chars to correlate residence time and particle combustion

Method:

- The tube oven is heated to a temperature of 1200 °C
- Residence time of 2, 4 and more seconds in the oven for single particles/pellets were conducted.
- The they are cooled immediately they are brought out of the oven with N2 gas to stop any further oxidation.





2 sec & 4 sec @ 1200 °C

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2 sec

4 sec

Aerodynamic **L**ift **V**elocity (ALV)

- **The aerodynamic properties of particle/pellets are characteristic parameters that are used to describe the ability of pellets to be fully suspended in air.**

- The term used in this case is **A**erodynamic **L**ift **V**elocity (ALV*). –Defined herein as the velocity of air in a fall column required to create the lift force necessary to just suspend the pellet above the mesh (see set-up).*

Experiments:

1. Particle/Pellets and Chars are dropped in a fall column one by one.
2. The amount of air flow required to just lift each particle is recorded.
3. Step 2 is repeated for several pellets and chars.

Test Set-Up Aerodynamic Lift Velocity

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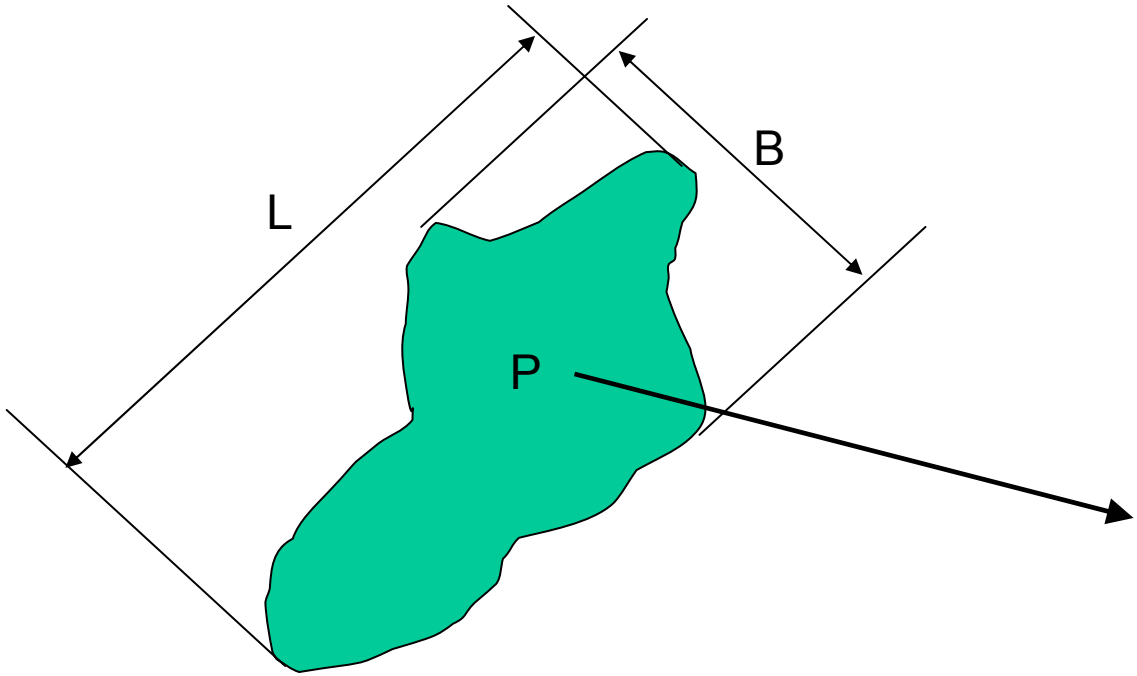
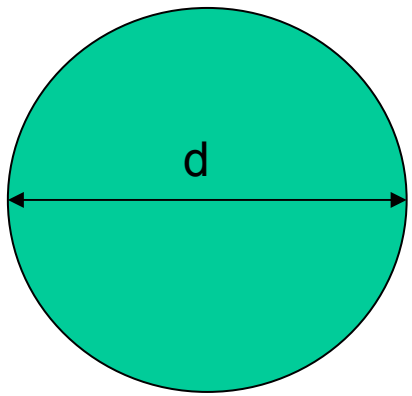
BACKGROUND



Circle with area equal to projected area of particle



L: Major axis length

B: Minor axis length

P: Max. projection area of particle

d: Equivalent diameter

Eccentricity (0-1)

Settling Velocity: PIAM vrs Sieve Analysis Method

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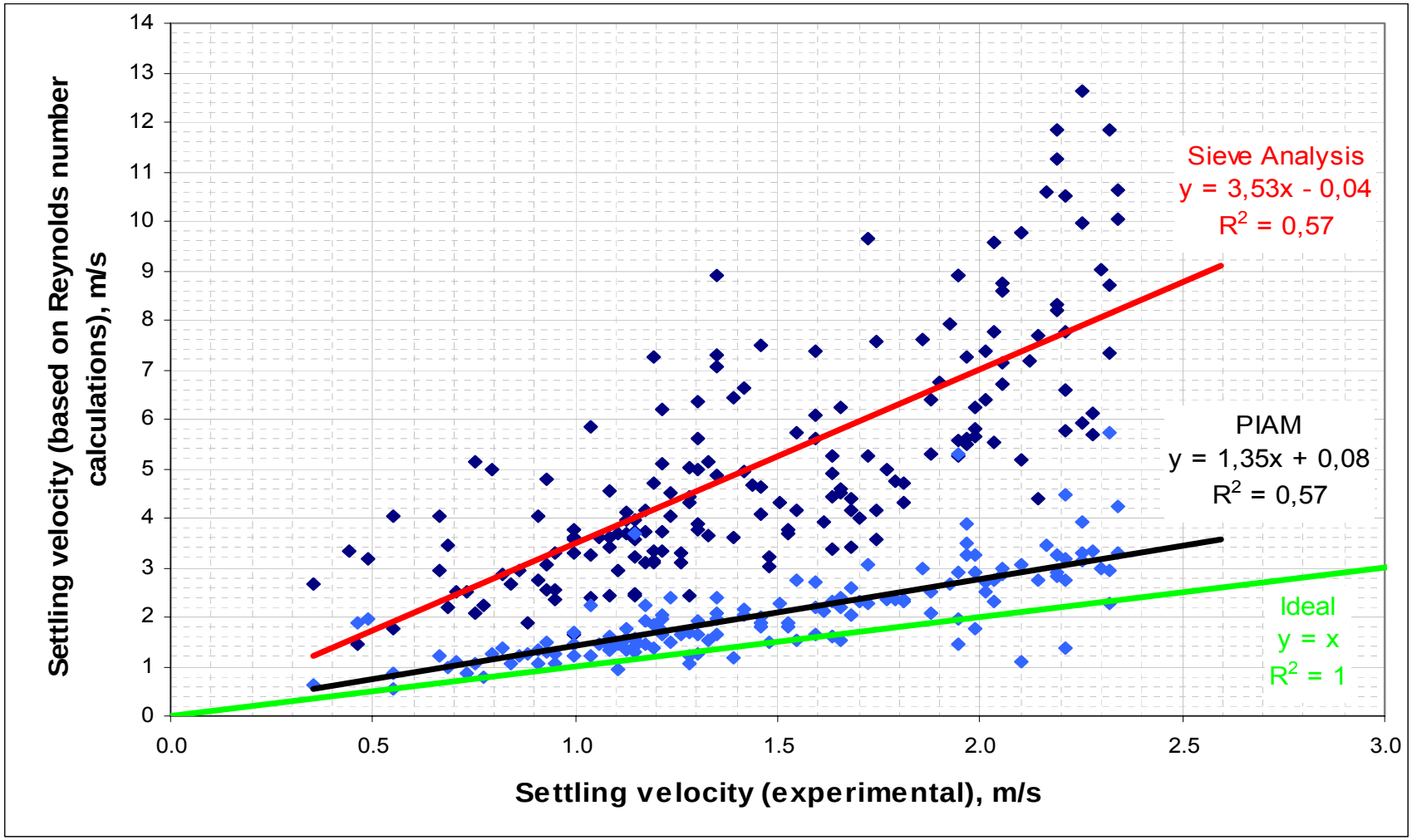

Concluding Remarks

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- Robust Standard Methods are available and under validation to determine physical properties of SRF and solid Biomass
- Advanced and automatic analysis methods are under development but further testing and finally validation is required
- The accuracy of predicting:
    - Particle trajectory,
    - Residence time,
    - Settling velocity, and
    - Flame position.

by CFD tools will substantially improved by the experimental determination of aerodynamic particle properties