Multi-fuel reactor introduction

May 5, 2009, Trondheim

by

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- Areas of use
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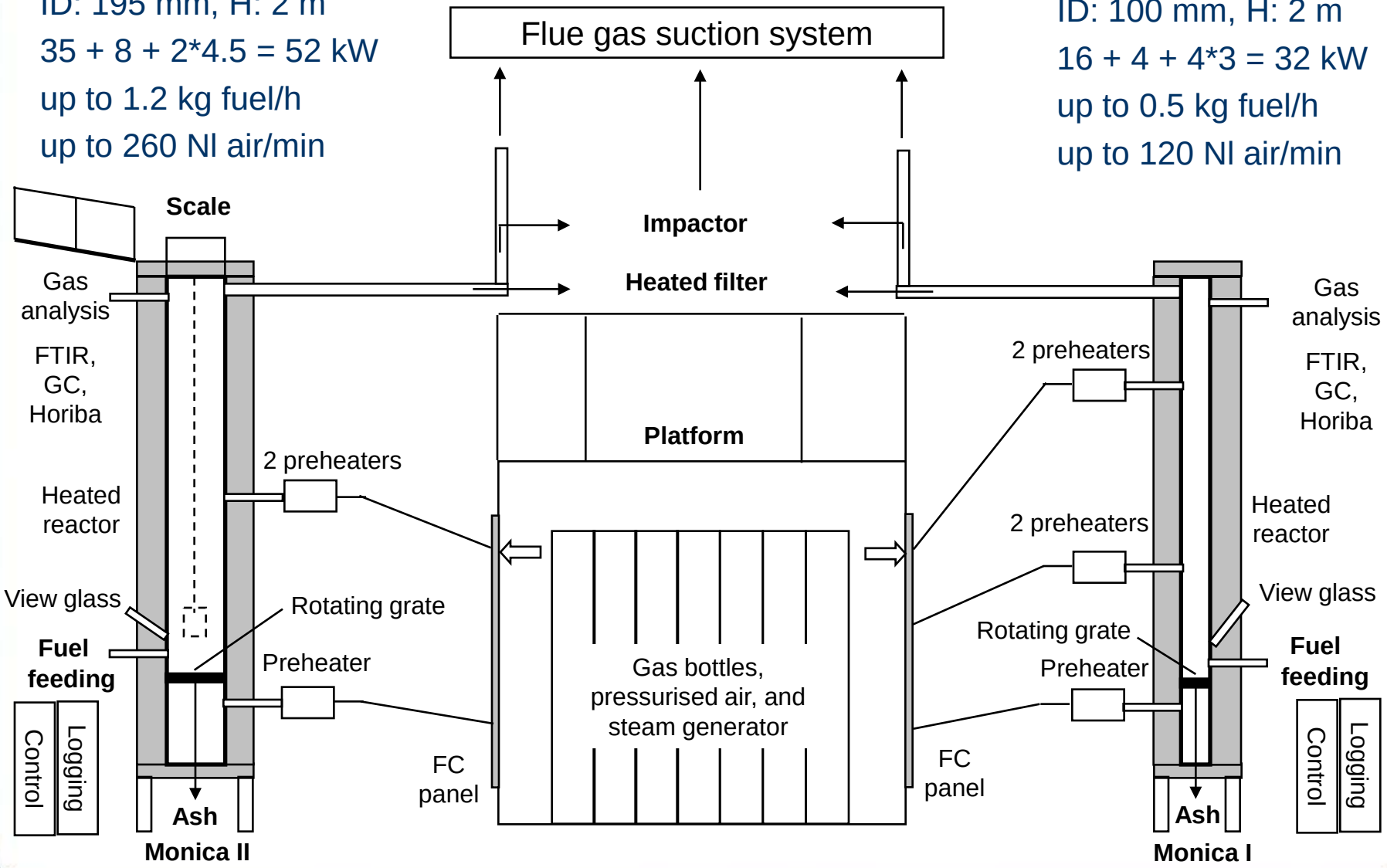
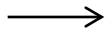
System overview

Key data:
up to 1100 °C
ID: 195 mm, H: 2 m
35 + 8 + 2*4.5 = 52 kW
up to 1.2 kg fuel/h
up to 260 Nl air/min

Key data:
up to 1300 °C
ID: 100 mm, H: 2 m
16 + 4 + 4*3 = 32 kW
up to 0.5 kg fuel/h
up to 120 Nl air/min



The multi-fuel reactor system



Areas of use

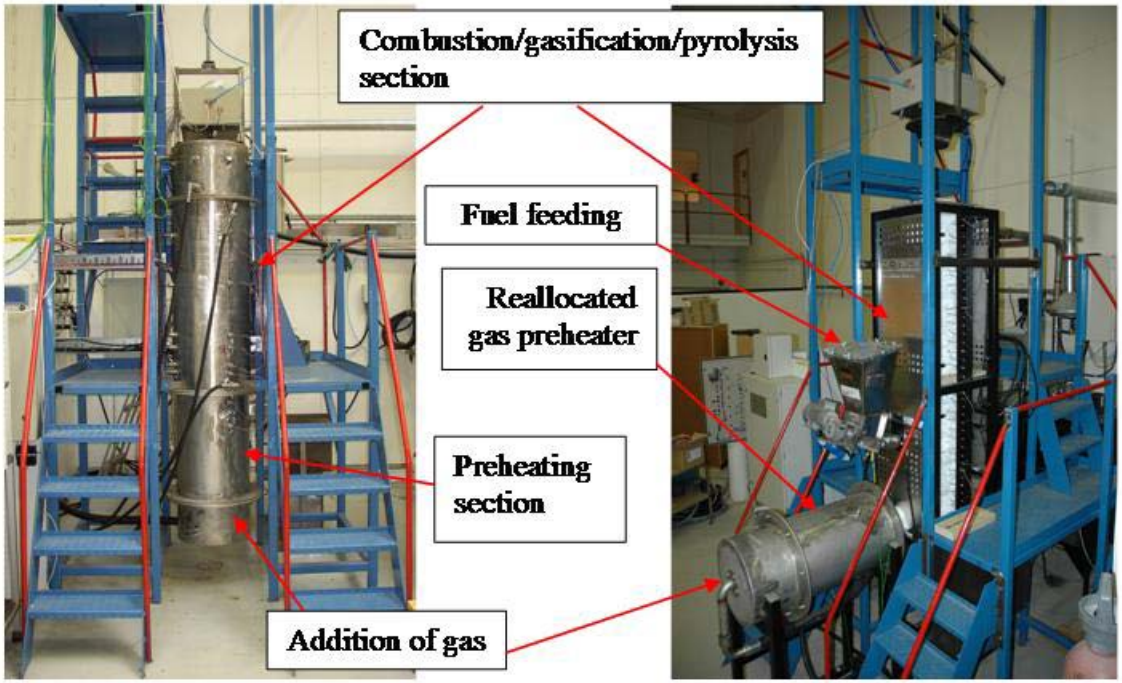
- Multi-fuel reactor
- Macro-TGA

- Combustion
  - Air staging possible
- Gasification
- Pyrolysis

History, and the construction

- Batch & macro-TGA
- Continous screw feeding & macro-TGA
- Continuous fuel feeding with rotating battery & macro-TGA
- Continuous fuel feeding with rotating battery in 2 new reactors
  - macro-TGA reactor, ID: 19.5 cm, 2 gas inlet stages
  - high temperature reactor, ID: 10 cm, 3 gas inlet stages

Original, first and second revision

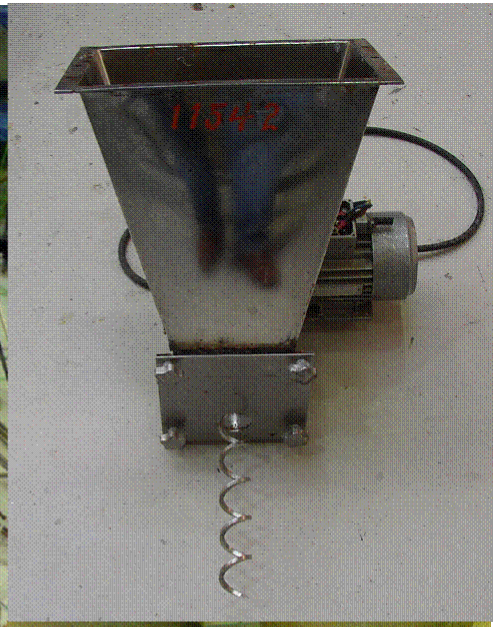


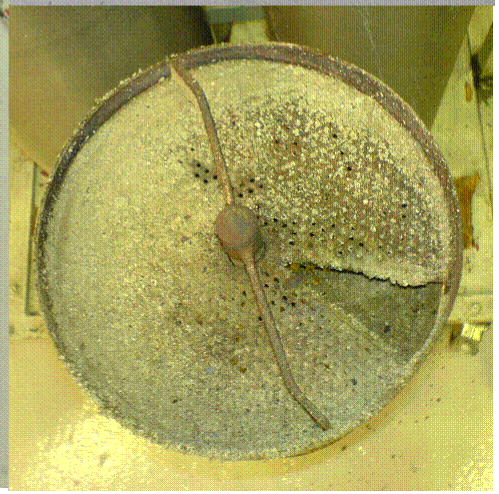
Before modifications

After modifications

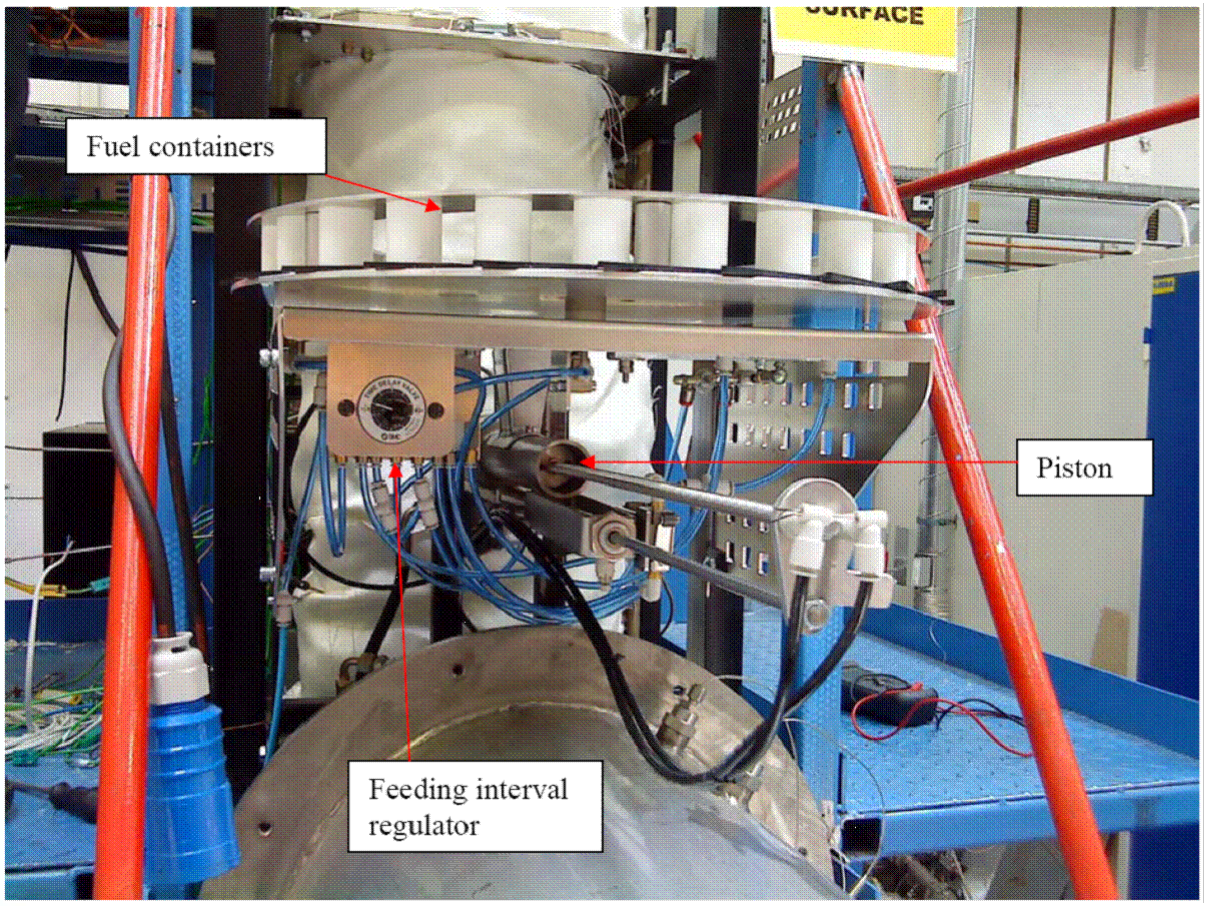
New fuel feeding system and modified grate

First revision

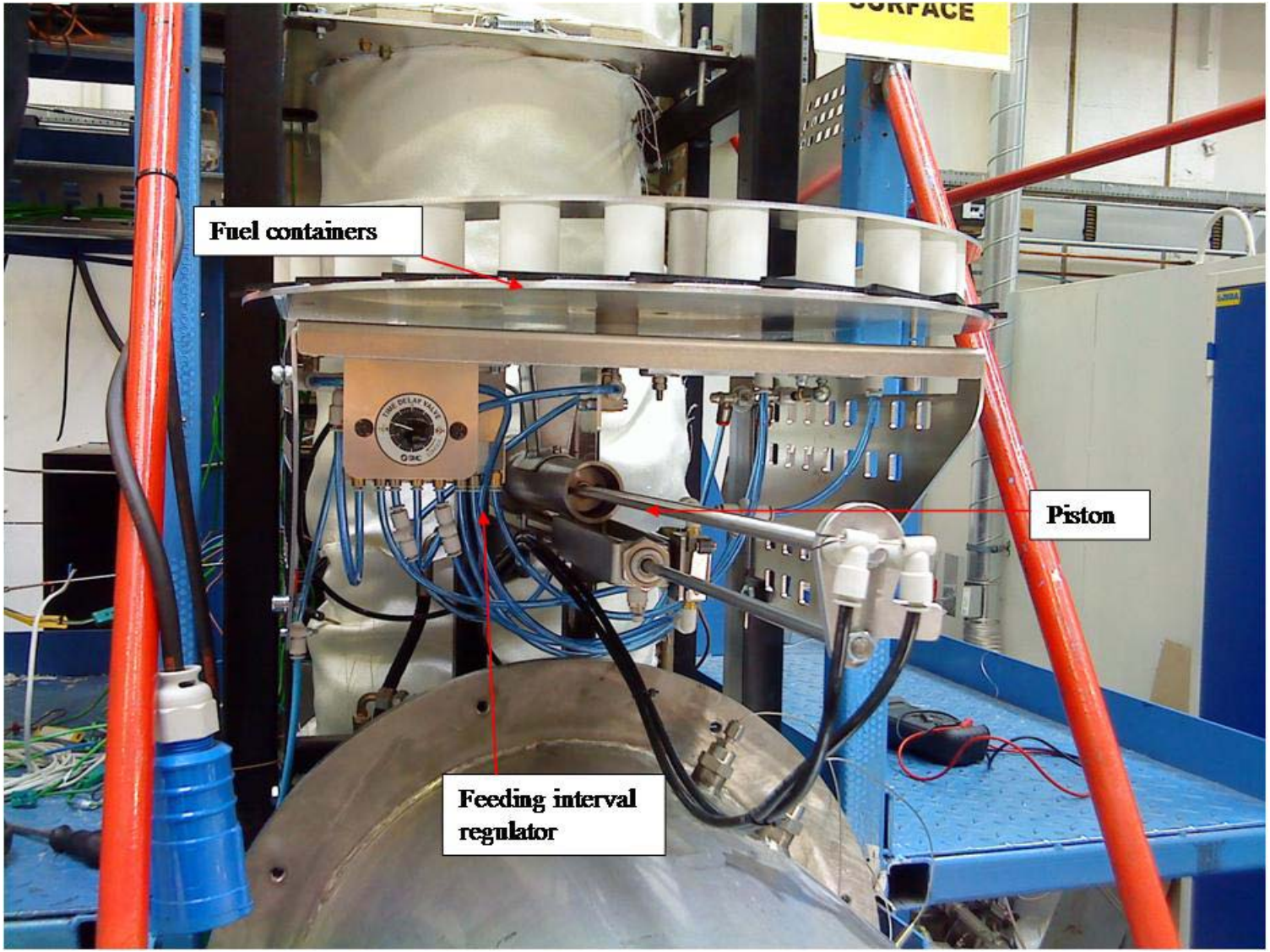




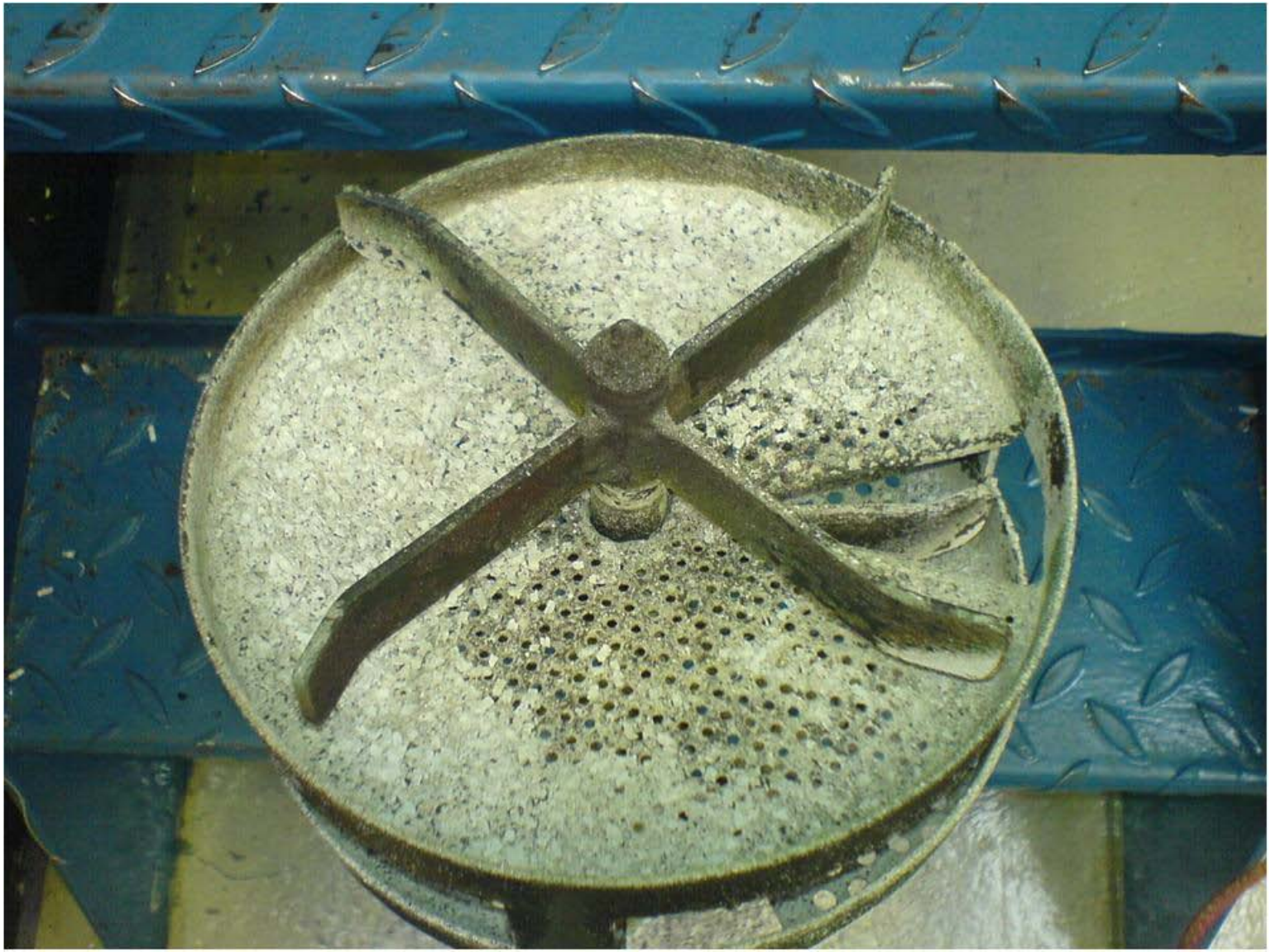
Second revision



Fuel feeding



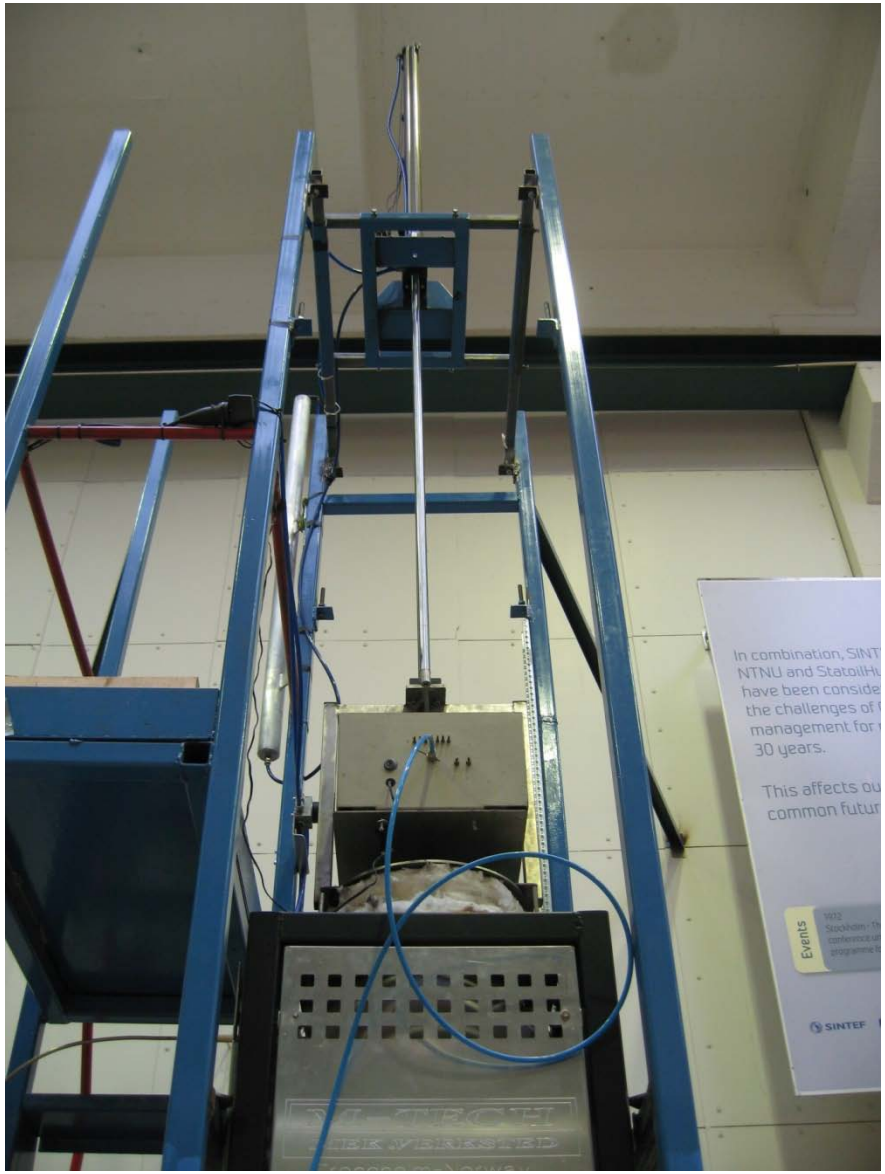
Grate



Ash bin

Fuel feeding

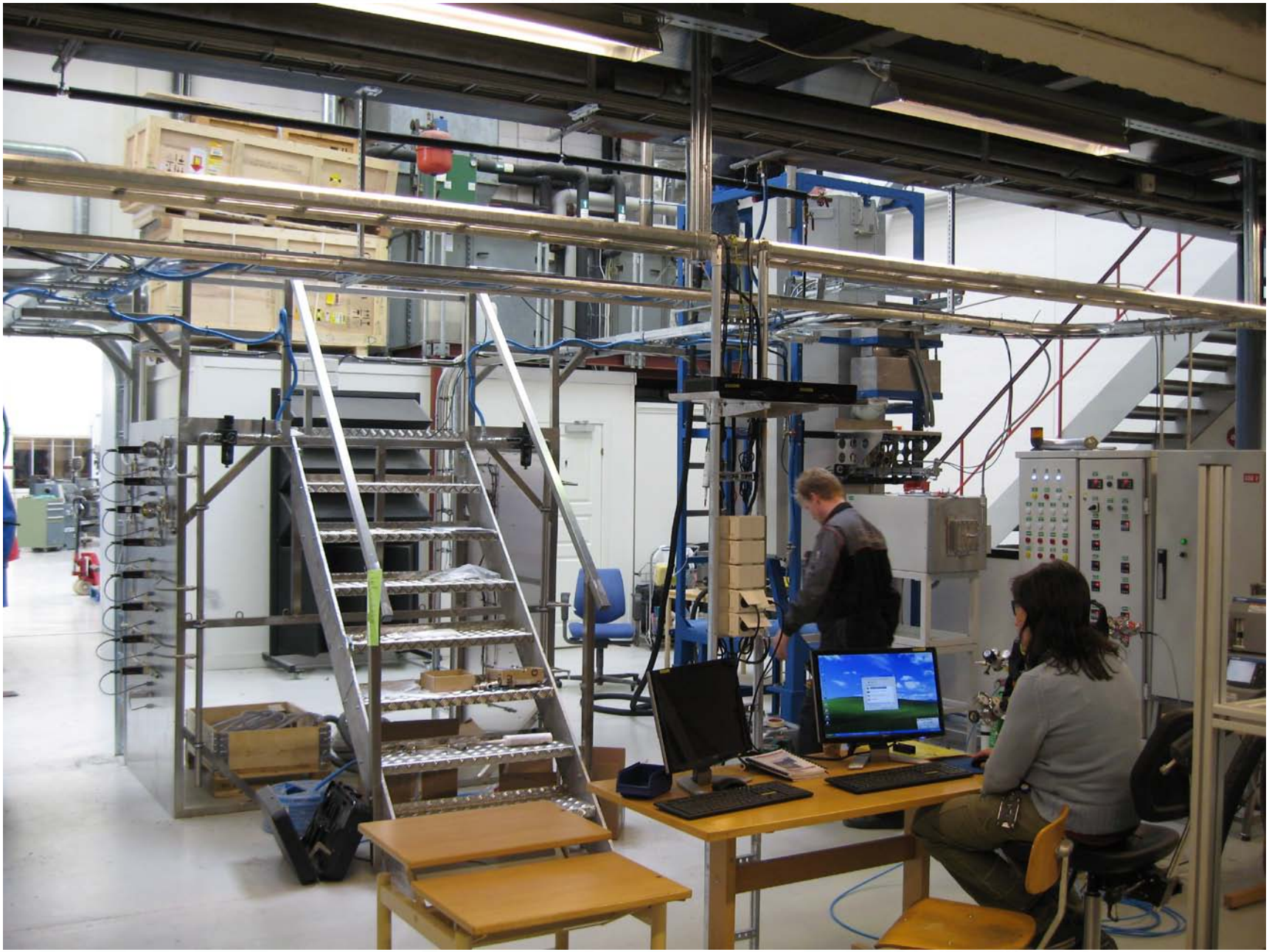
Scale



Monica II, with macro-TGA

New reactors!

Monica I, 1300 °C



Reactor specifications

Monica I

2./ TECHNICAL DATA OF THE FURNACE

Furnace chamber	:	Ø100x2000	mm
Mass	:	800	kg
Maximal operating temperature	:	1300	C°
Nominal operating voltage	:	3x400	V
Nominal power	:	16	kW
Temperature measurement	:	with P type Pt-PtRh thermocouple	
Temperature control	:	with HAGA KD9 type instrument	
General prescriptions	:	79/1997./XII.31./sz.IKIM r.	
Class of protection against indirect contact	:	MSZ 2364	

Reactor specifications

Monica II

2./ TECHNICAL DATA OF THE FURNACE

Furnace chamber	:	Ø195x2000	mm
Mass	:	1000	kg
Maximal operating temperature	:	1100	C°
Nominal operating voltage	:	3x400	V
Nominal power	:	35	kW
Temperature measurement	:	with K type Ni-NiCr thermocouple	
Temperature control	:	with HAGA KD9 type instrument	
General prescriptions	:	79/1997./XII.31./sz.IKIM r.	
Class of protection against indirect contact	:	MSZ 2364	

Reactor specifications

Ceramic tube

EK Security Data Sheet
Security Data Sheet according to Guidelines Nr. 91/155 of the European Union.

1. Chemical or manufacture:
1.1, Name of the chemical: HEAT-RESISTANT CERAMIC POWDER: **7032**
1.2, Field of use: Fireproof materials
1.3, Manufacturer: Fazékkő Kft
H-1147 Budapest, Telepes u. 12.
Phone: 36-1-417-38-59

2., Composition:
Chemical composition: Natural clay minerals with min. 40% Al_2O_3 content

Illite CAS: 106958-53-6 > 30%	$(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$
Kaoline CAS: 1318-47-7 > 30%	$Al_2Si_2O_5(OH)_4$
Al_2O_3 CAS: 90669-62-8 > 10%	
Talc AS: 14807-96-6 > 10%	$H_2Mg_3(SiO_3)_4$ or $Mg_3Si_4O_{10}(OH)_2$

3., Danger classification:
Danger classification according to aspects of labour hygiene and environmental protection.
EC/R: Non-dangerous material.

Reactor heating

Primary air preheater design

Control

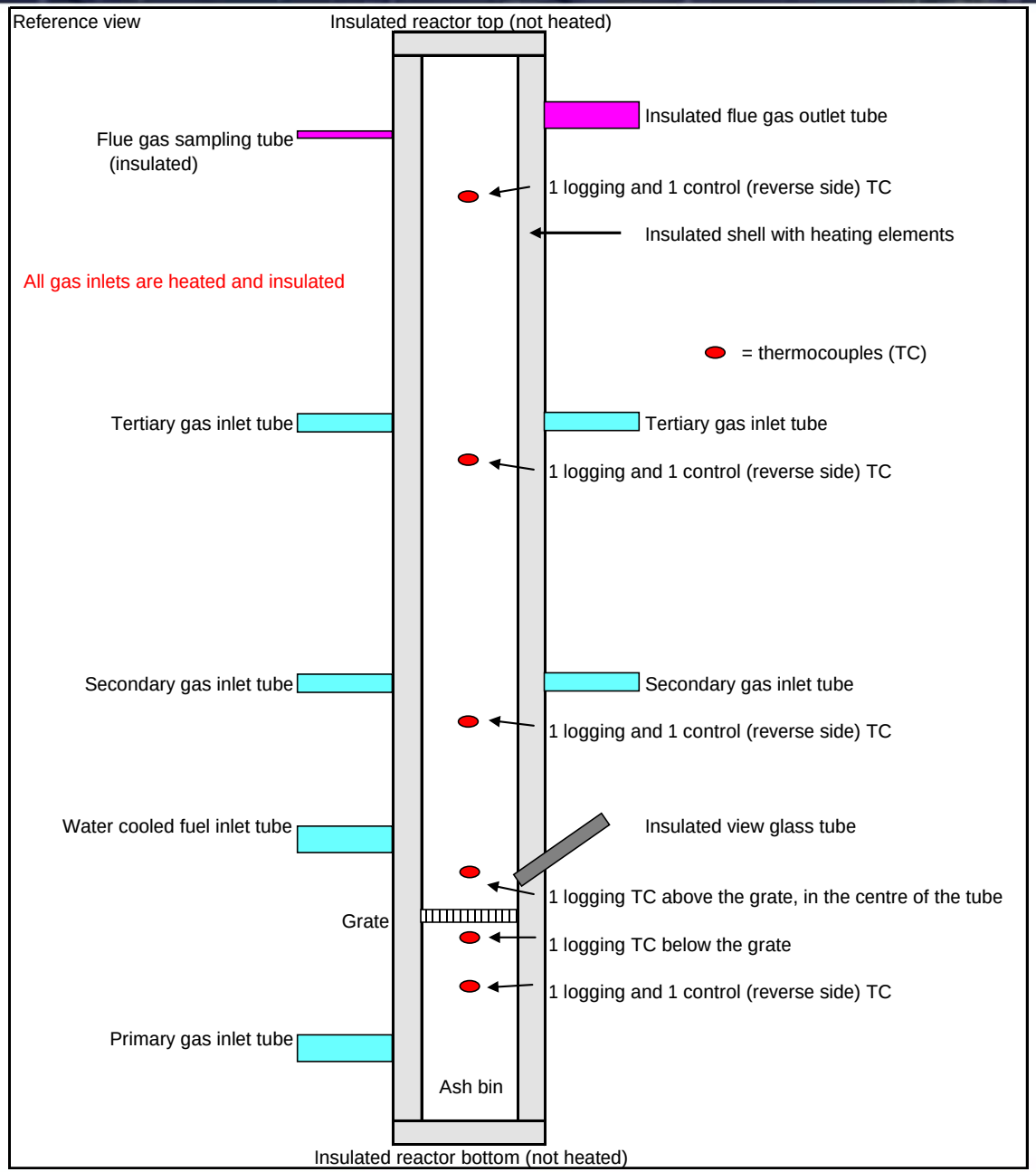
Monica II

Monica I

Logging

Data logging cabinet for each reactor

Monica I


Reference view
Insulated reactor top (not heated)
Insulated flue gas outlet tube
Flue gas sampling tube (insulated)
1 logging and 1 control (reverse side) TC
Insulated shell with heating elements
All gas inlets are heated and insulated
= thermocouples (TC)
Tertiary gas inlet tube
Tertiary gas inlet tube
1 logging and 1 control (reverse side) TC
Secondary gas inlet tube
Secondary gas inlet tube
1 logging and 1 control (reverse side) TC
Water cooled fuel inlet tube
Insulated view glass tube
1 logging TC above the grate, in the centre of the tube
Grate
1 logging TC below the grate
1 logging and 1 control (reverse side) TC
Primary gas inlet tube
Ash bin
Insulated reactor bottom (not heated)

Monica I

For combustion conditions:

Fuel feeding rate: up to 0.5 kg/h

Max inlet gas flow (using air) demand: 120 Nl/min

Max gas flow (using air) in reactor after fuel conversion: 130 Nl/min

Max residence time in reactor (section above grate, 1.6 m high): 10 s

Minimum residence time in reactor (section above grate, 1.6 m high): 1 s

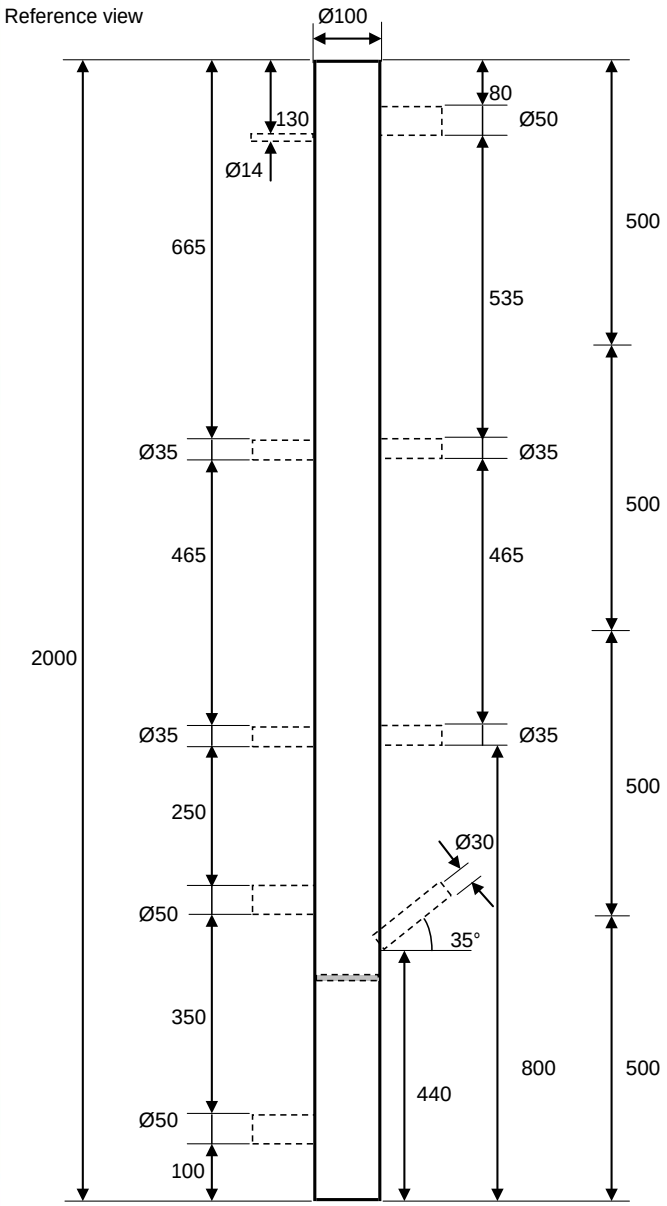
Max gas flow speed: 1.6 m/s, corresponding to a Reynolds number of about 800

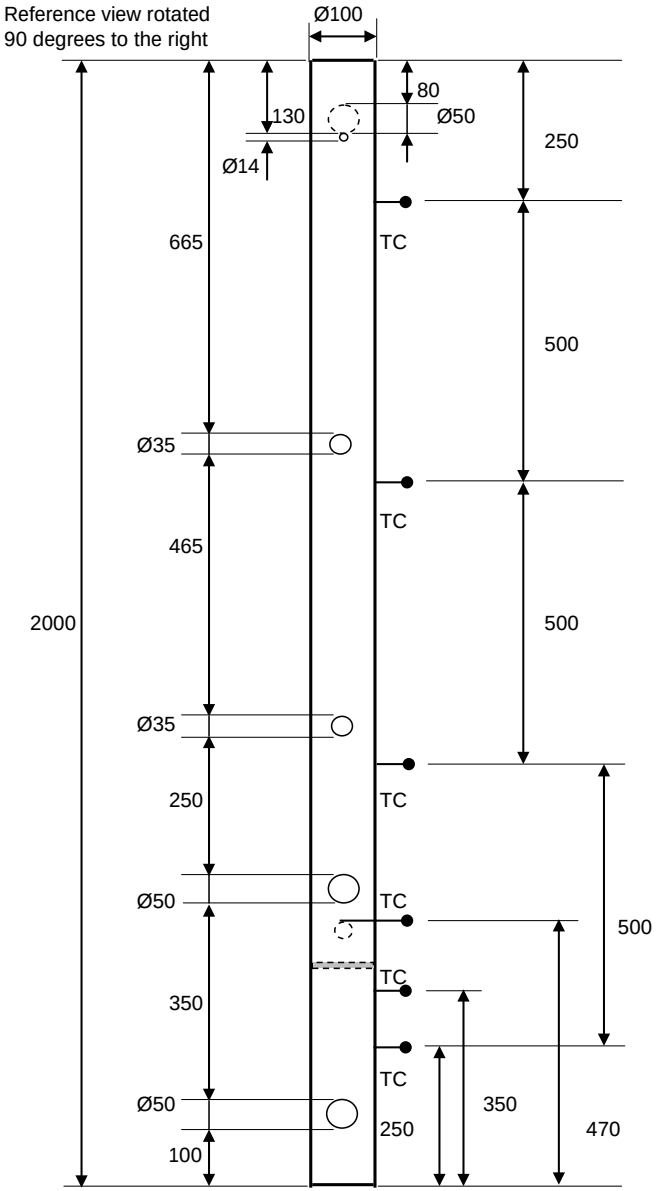
Minimum gas flow speed: 0.16 m/s, corresponding to a Reynolds number of about 150

Max net inlet gas flow preheating effect in external preheater (using air, 1300°C): 3.5 kW

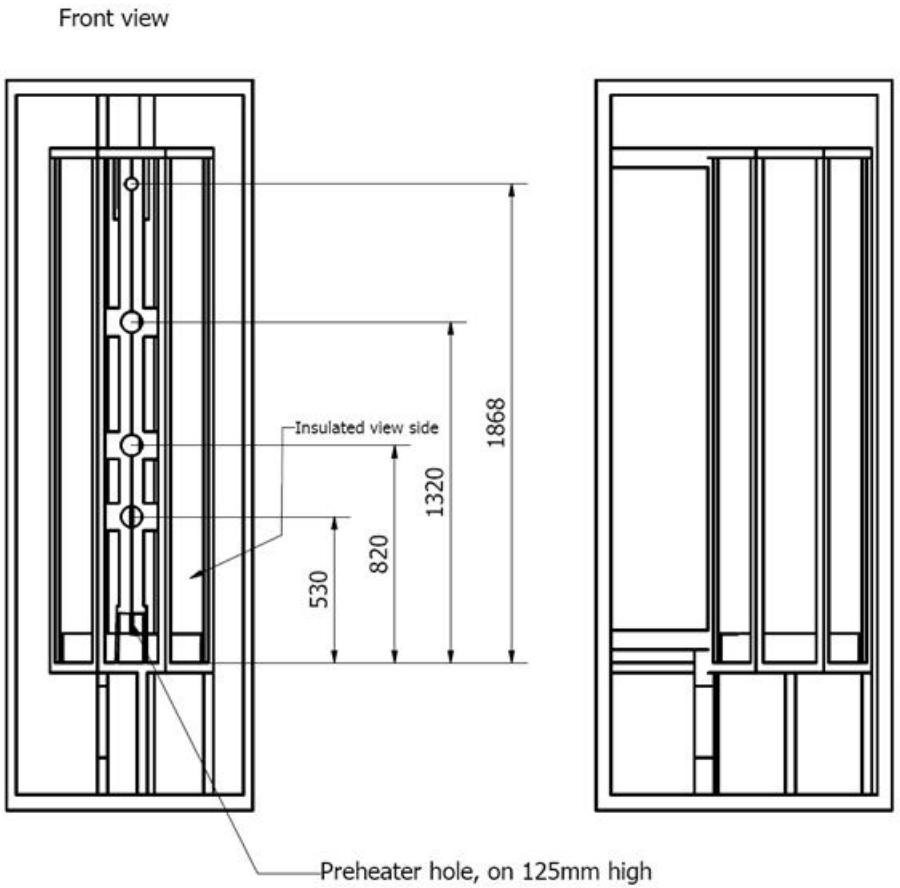
Max energy release, from fuel, due to reactions: 2.5 kW

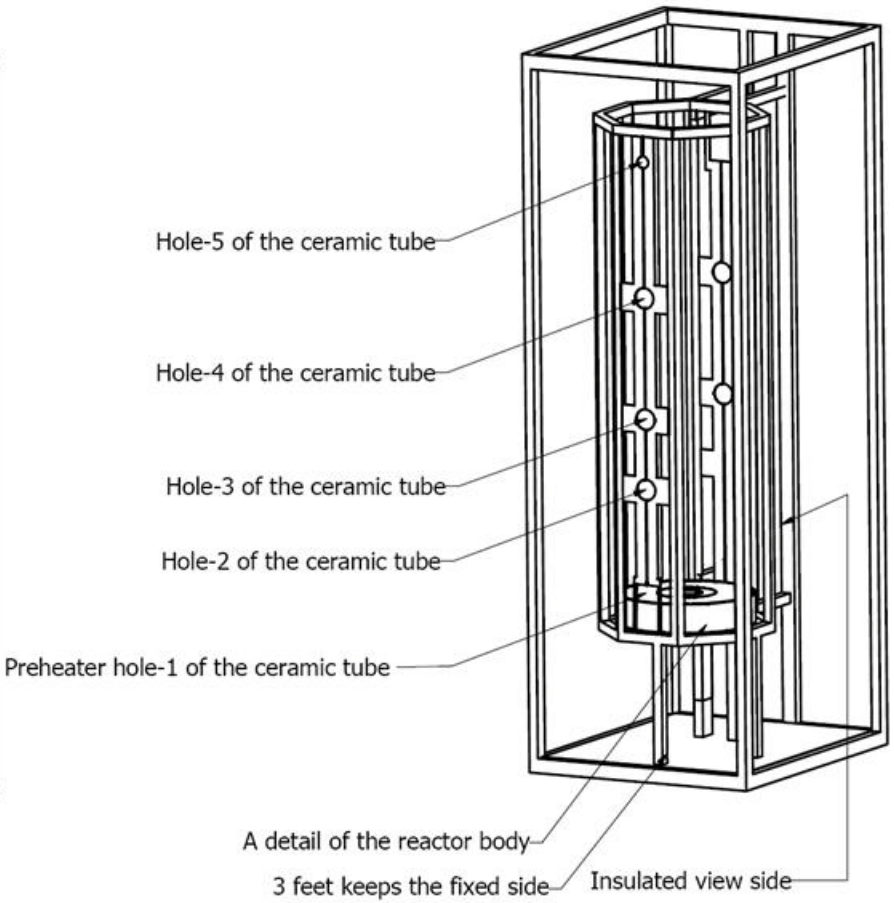
Monica I


Reference view
Ø100
80
Ø50
130
Ø14
665
535
500
Ø35
Ø35
500
465
465
2000
Ø35
Ø35
500
250
Ø30
Ø50
35°
350
440
800
500
Ø50
100

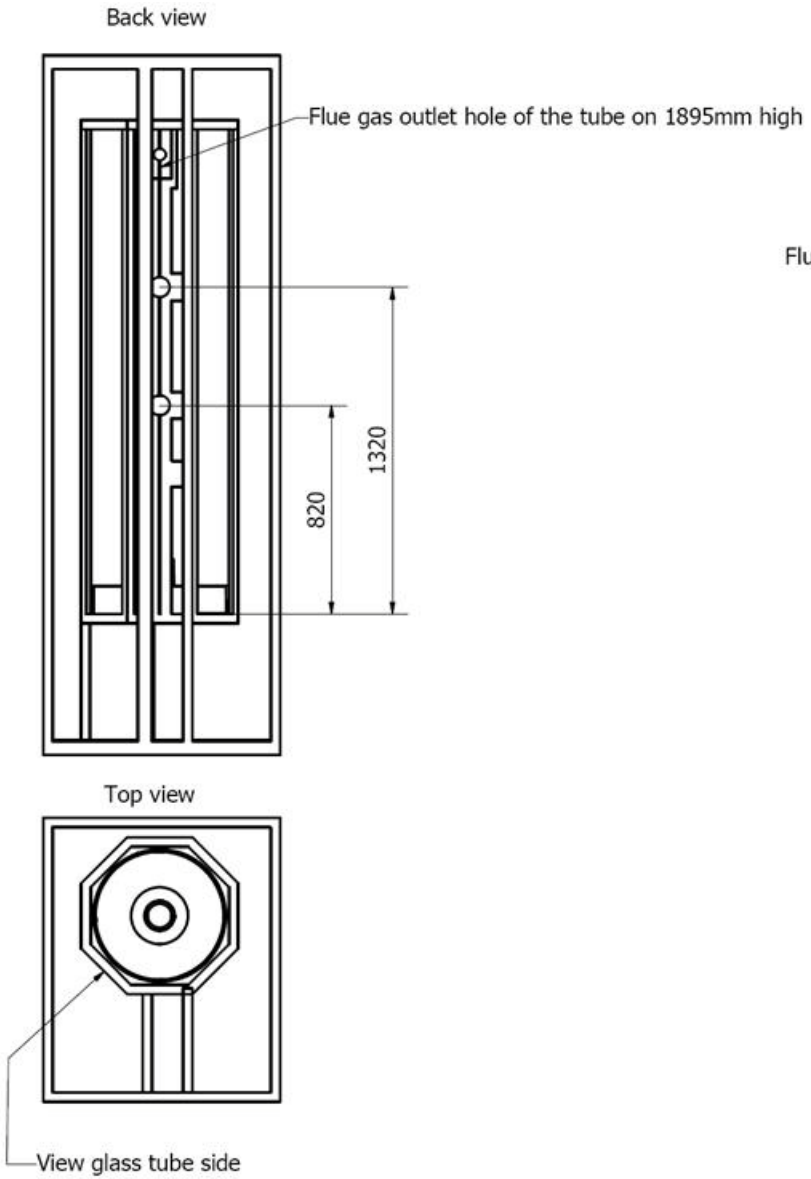

Reference view rotated
90 degrees to the right
Ø100
80
Ø50
130
Ø14
250
665
TC
500
Ø35
TC
465
500
2000
Ø35
TC
250
Ø50
TC
500
TC
350
TC
Ø50
350
470
250
100

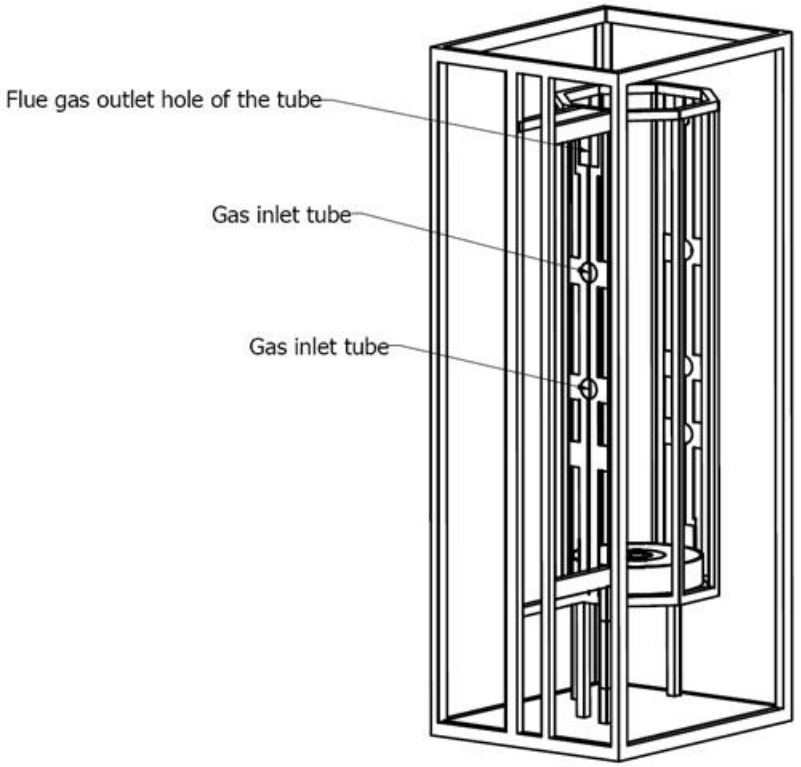
Monica I


Front view
Insulated view side
1868
1320
820
530
Preheater hole, on 125mm high


Hole-5 of the ceramic tube
Hole-4 of the ceramic tube
Hole-3 of the ceramic tube
Hole-2 of the ceramic tube
Preheater hole-1 of the ceramic tube
A detail of the reactor body
3 feet keeps the fixed side
Insulated view side

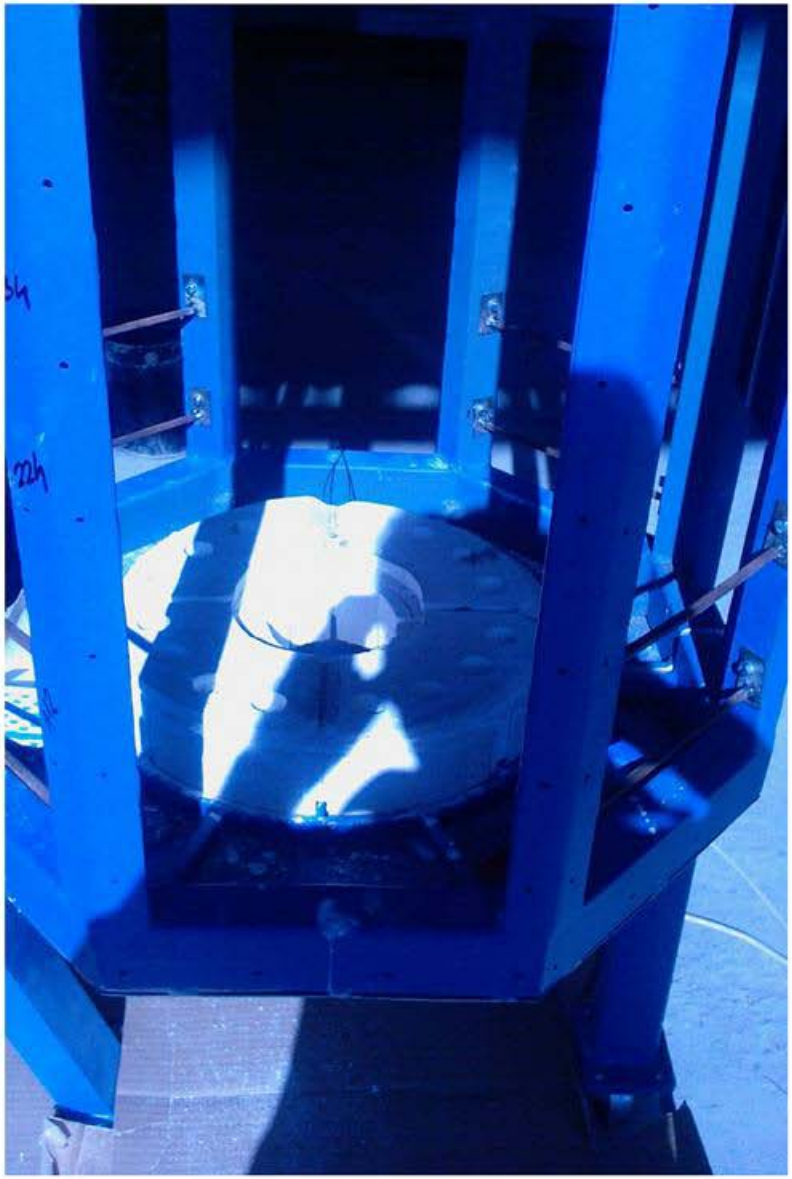
Monica I



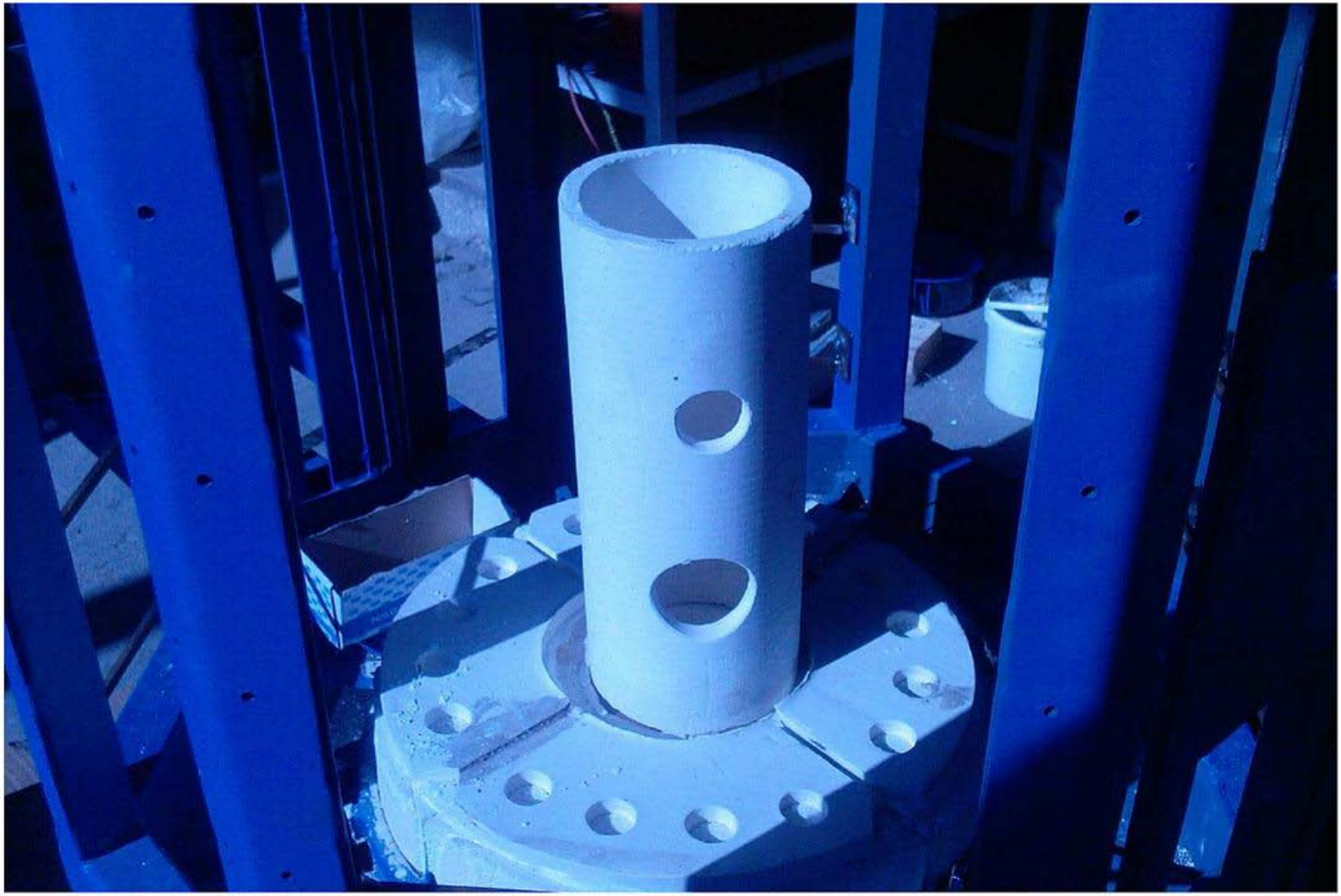


Tervező	Ellenőrizte	Jóváhagyta	Dátum	
Peti				
Reactor body without covering				

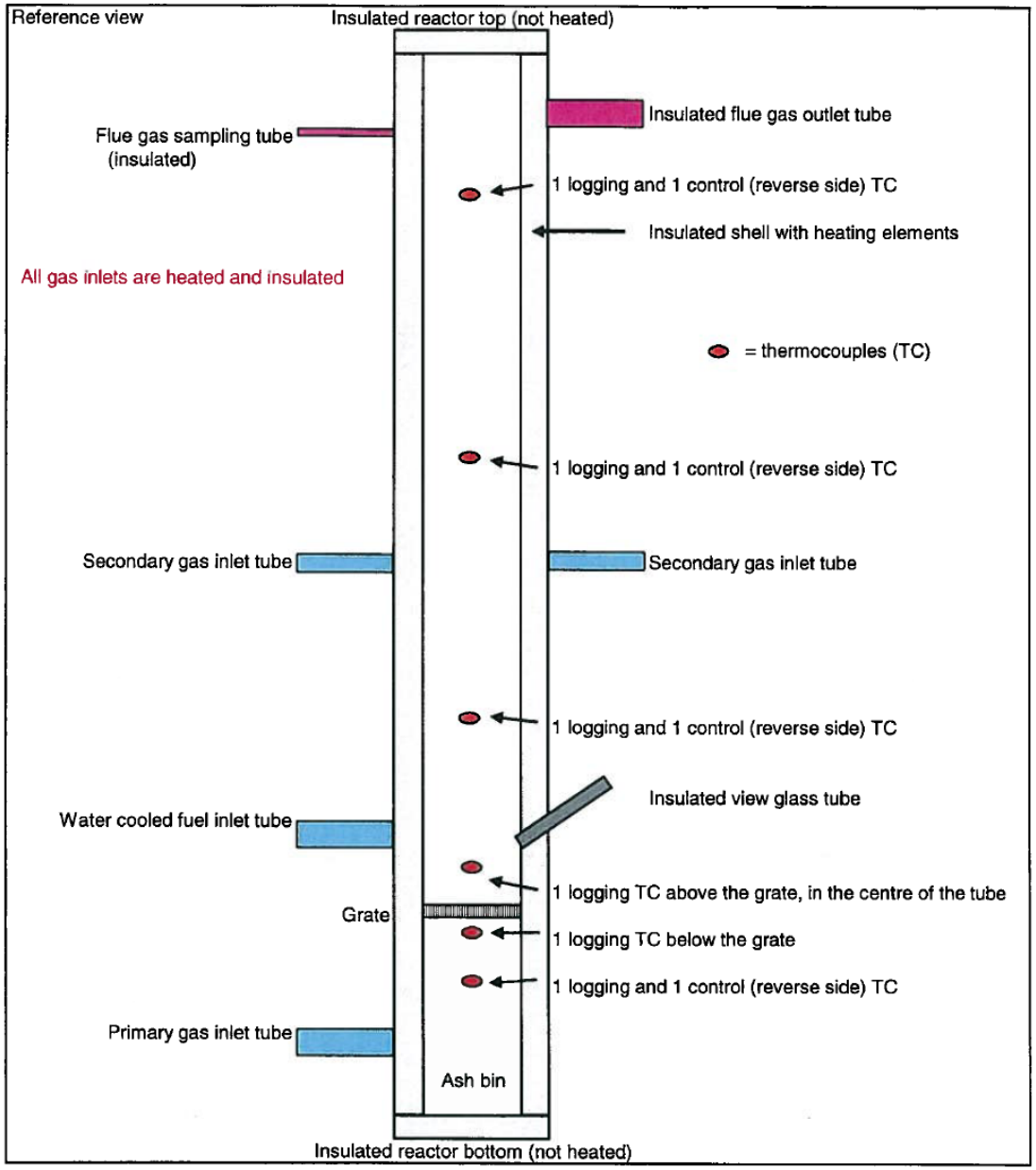
Monica I



Monica I



Monica II


Reference view
Insulated reactor top (not heated)
Insulated flue gas outlet tube
Flue gas sampling tube (insulated)
1 logging and 1 control (reverse side) TC
Insulated shell with heating elements
All gas inlets are heated and insulated
= thermocouples (TC)
1 logging and 1 control (reverse side) TC
Secondary gas inlet tube
Secondary gas inlet tube
1 logging and 1 control (reverse side) TC
Insulated view glass tube
Water cooled fuel inlet tube
1 logging TC above the grate, in the centre of the tube
Grate
1 logging TC below the grate
1 logging and 1 control (reverse side) TC
Primary gas inlet tube
Ash bin
Insulated reactor bottom (not heated)

Monica II

For combustion conditions:

Fuel feeding rate: up to 1.2 kg/h

Max inlet gas flow (using air) demand: 260 Nl/min

Max gas flow (using air) in reactor after fuel conversion: 275 Nl/min

Max residence time in reactor (section above grate, 1.6 m high): 11 s

Minimum residence time in reactor (section above grate, 1.6 m high): 2 s

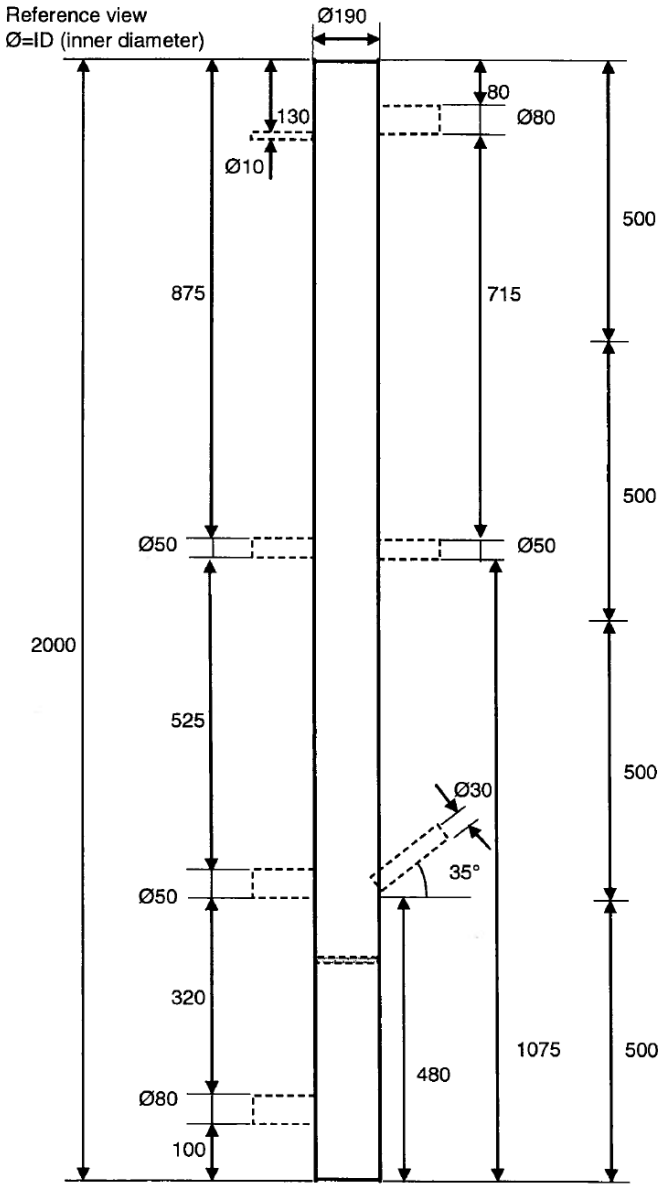
Max gas flow speed: 0.8 m/s, corresponding to a Reynolds number of about 1000

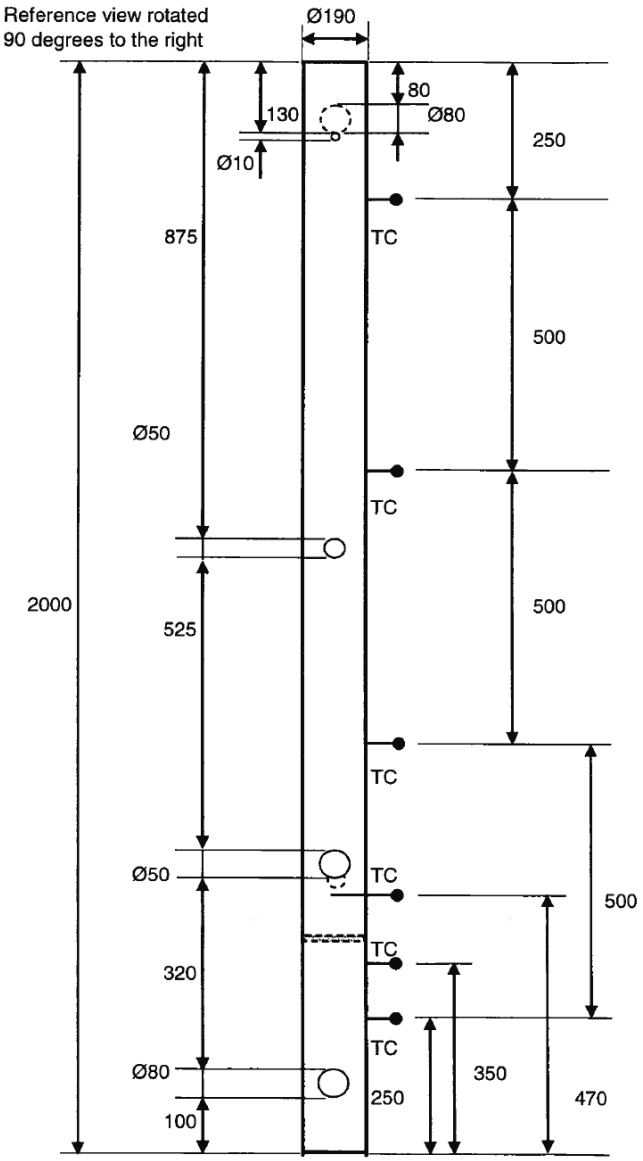
Minimum gas flow speed: 0.15 m/s, corresponding to a Reynolds number of about 220

Max net inlet gas flow preheating effect in external preheater (using air, 1100°C): 6.7 kW

Max energy release, from fuel, due to reactions: 5.8 kW

Monica II

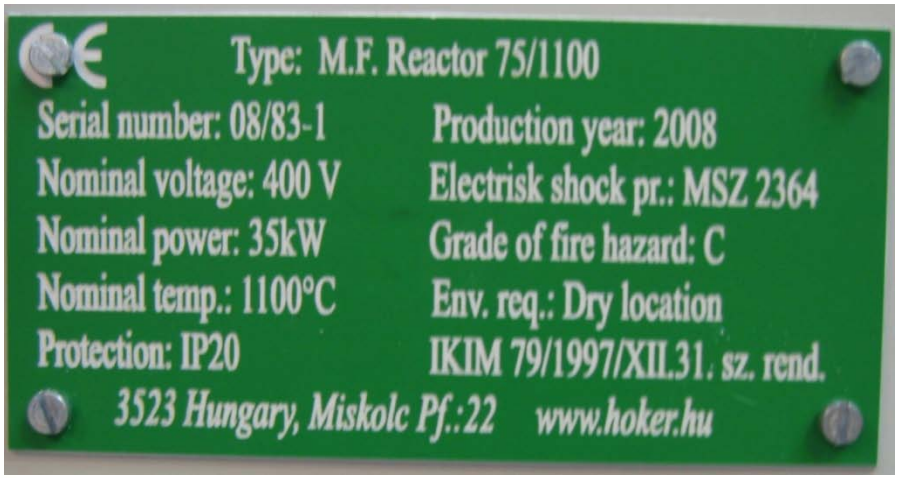

Reference view
Ø=ID (inner diameter)
Ø190
130
Ø10
80
Ø80
875
715
500
500
500
500
Ø50
Ø50
2000
525
Ø30
35°
Ø50
320
480
1075
Ø80
100

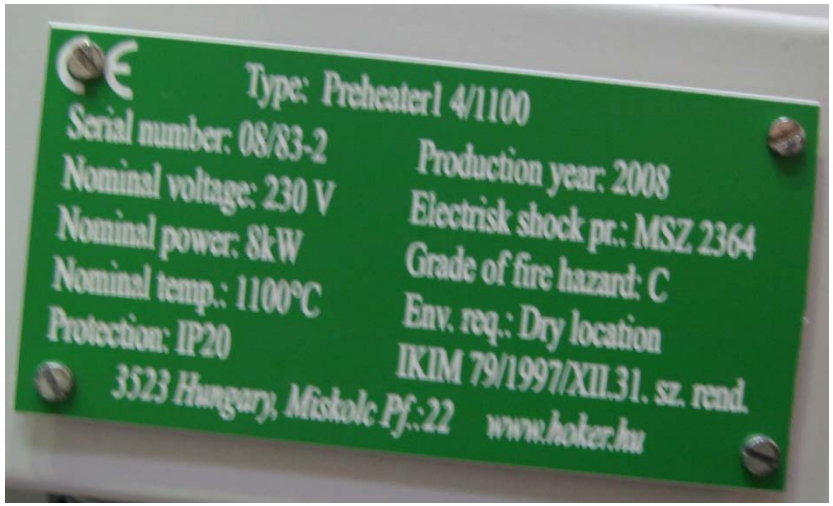

Reference view rotated
90 degrees to the right
Ø190
130
Ø10
80
Ø80
250
875
TC
500
Ø50
TC
2000
525
500
TC
TC
Ø50
TC
500
TC
320
TC
Ø80
250
350
470
100

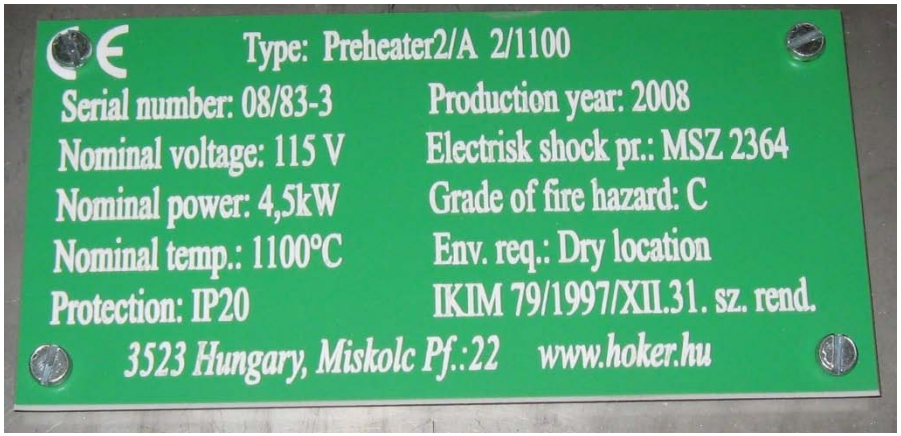
Monica II

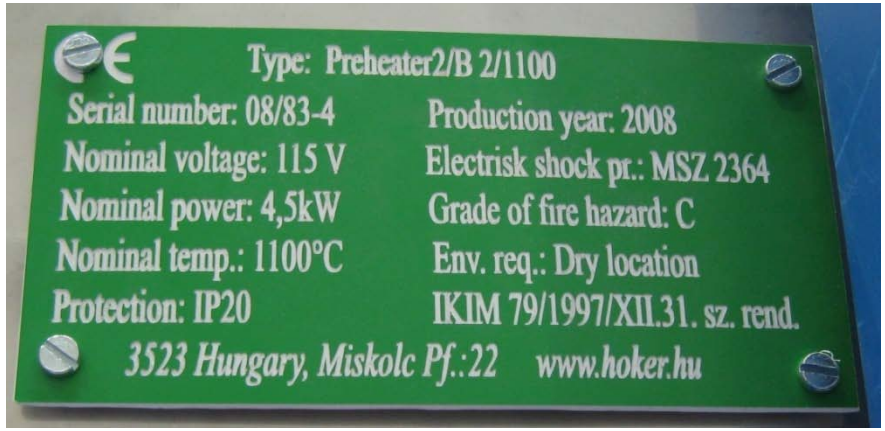
Monica II

Monica II heaters

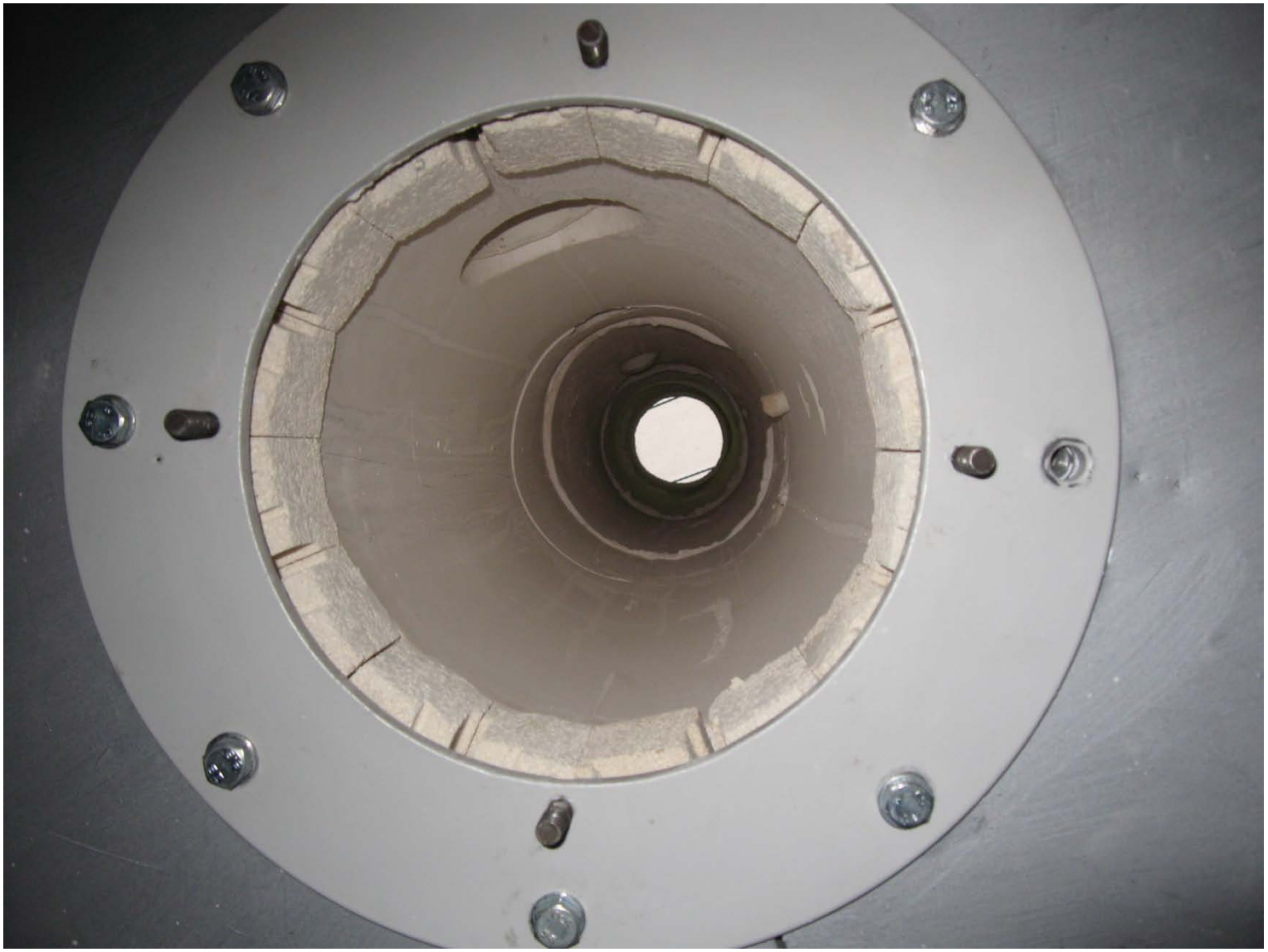








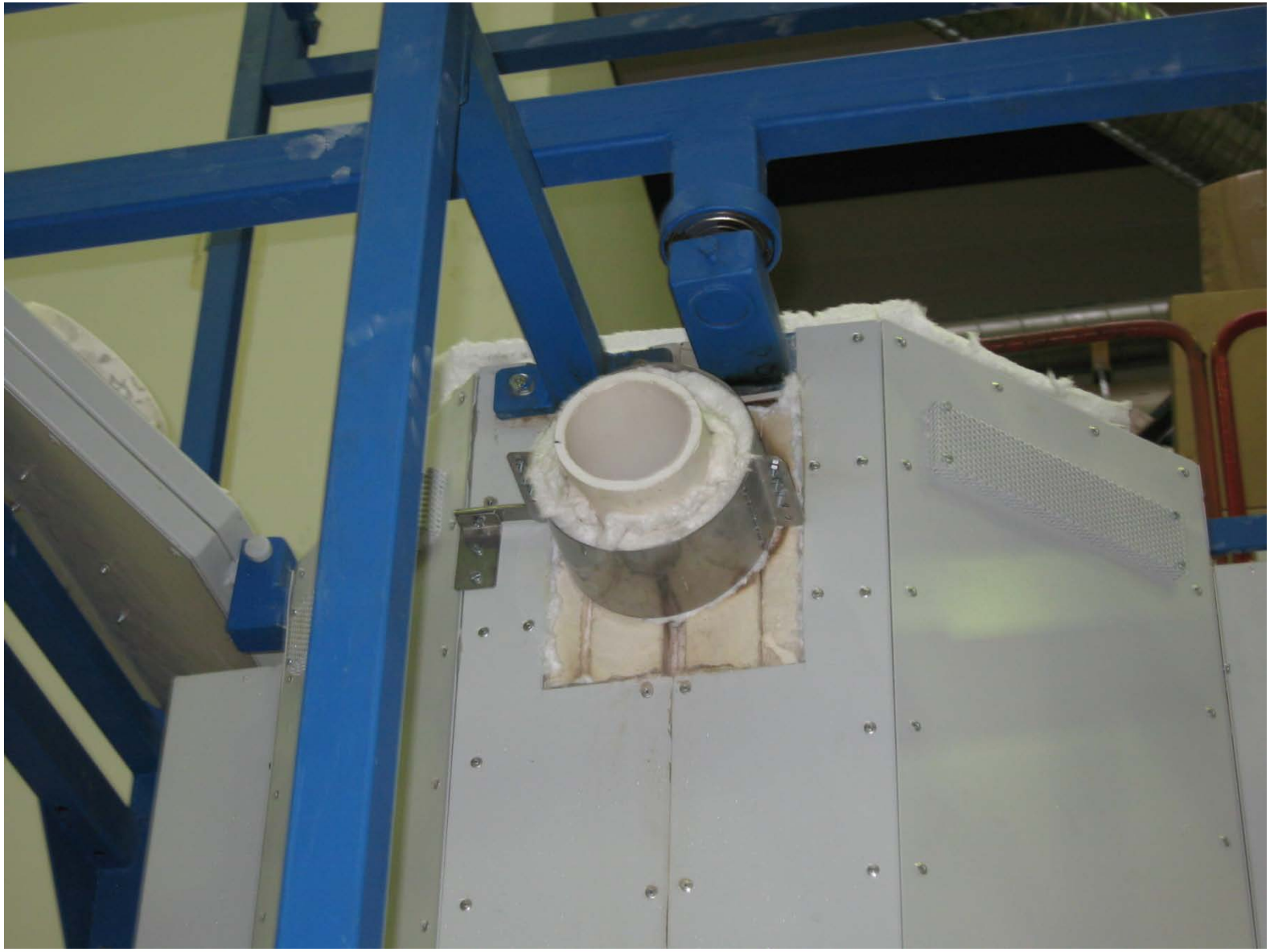
Monica II reactor tube



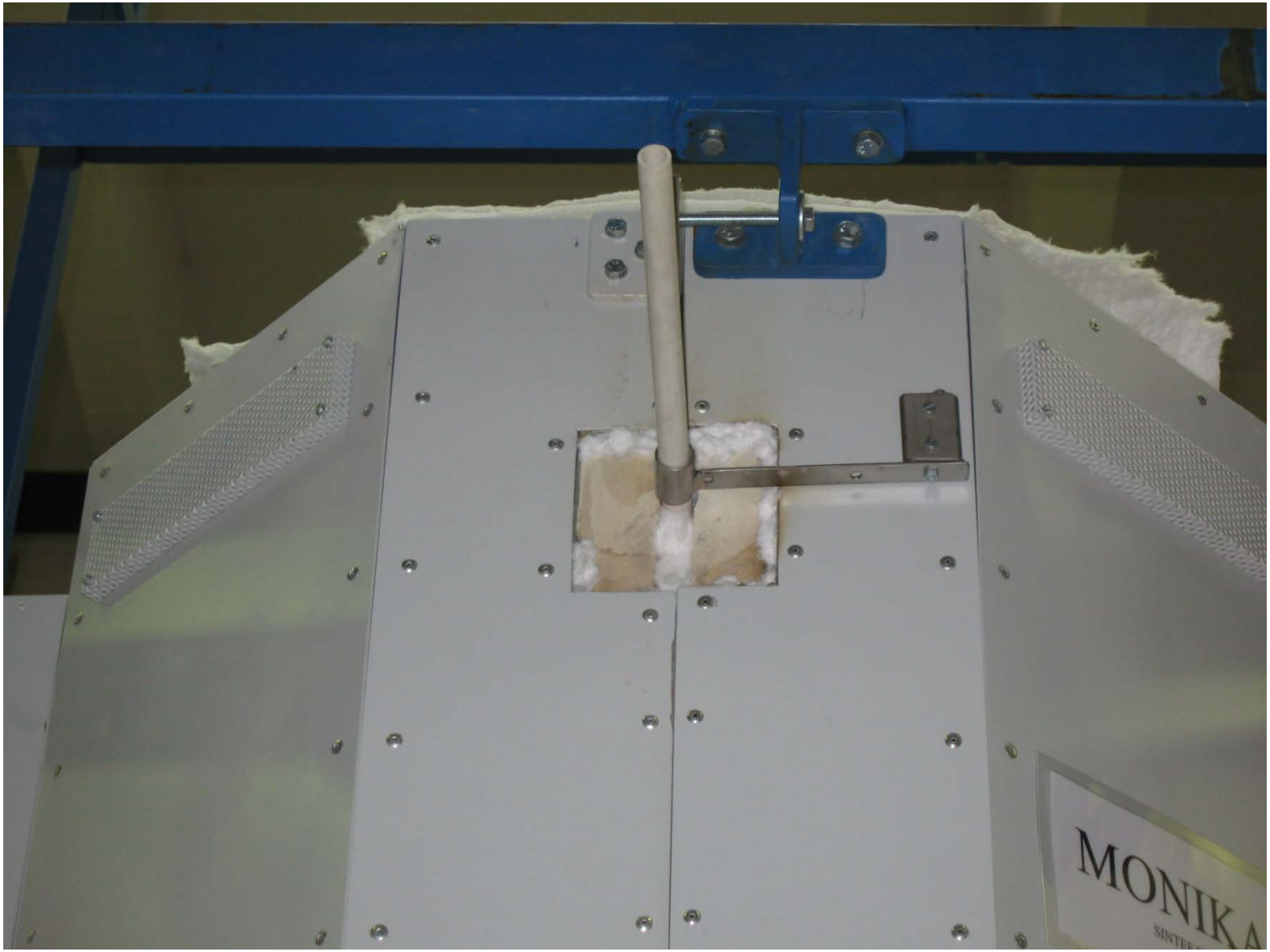
Monica II bottom and top plugs

Monica II fuel inlet

Monica II flue gas outlet



Monica II flue gas sampling outlet



Monica II view glass

Platform

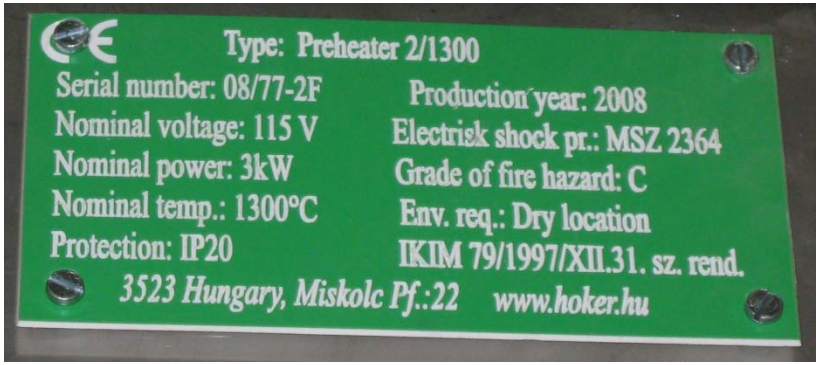
Monica II FC panel

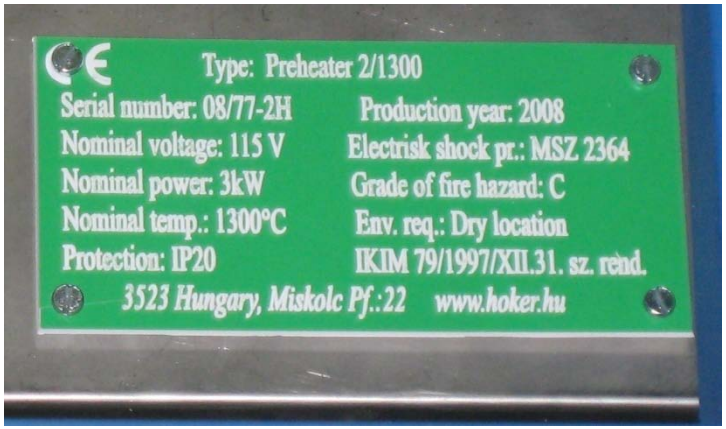
Monica I FC panel

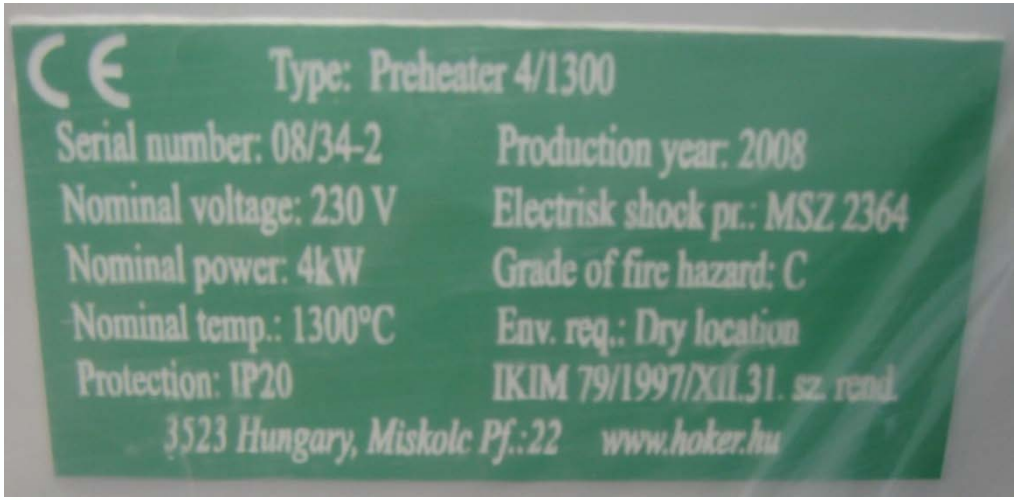
Monica I

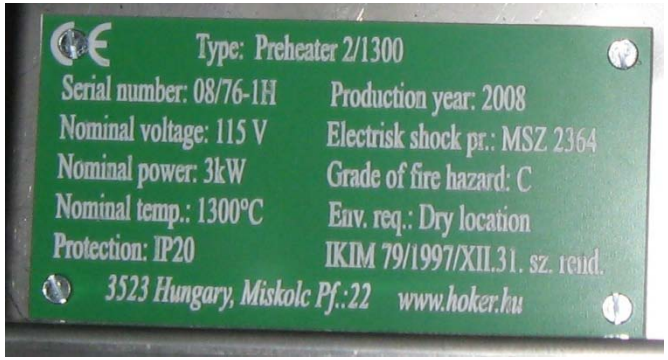
Monica I

Monica I heaters

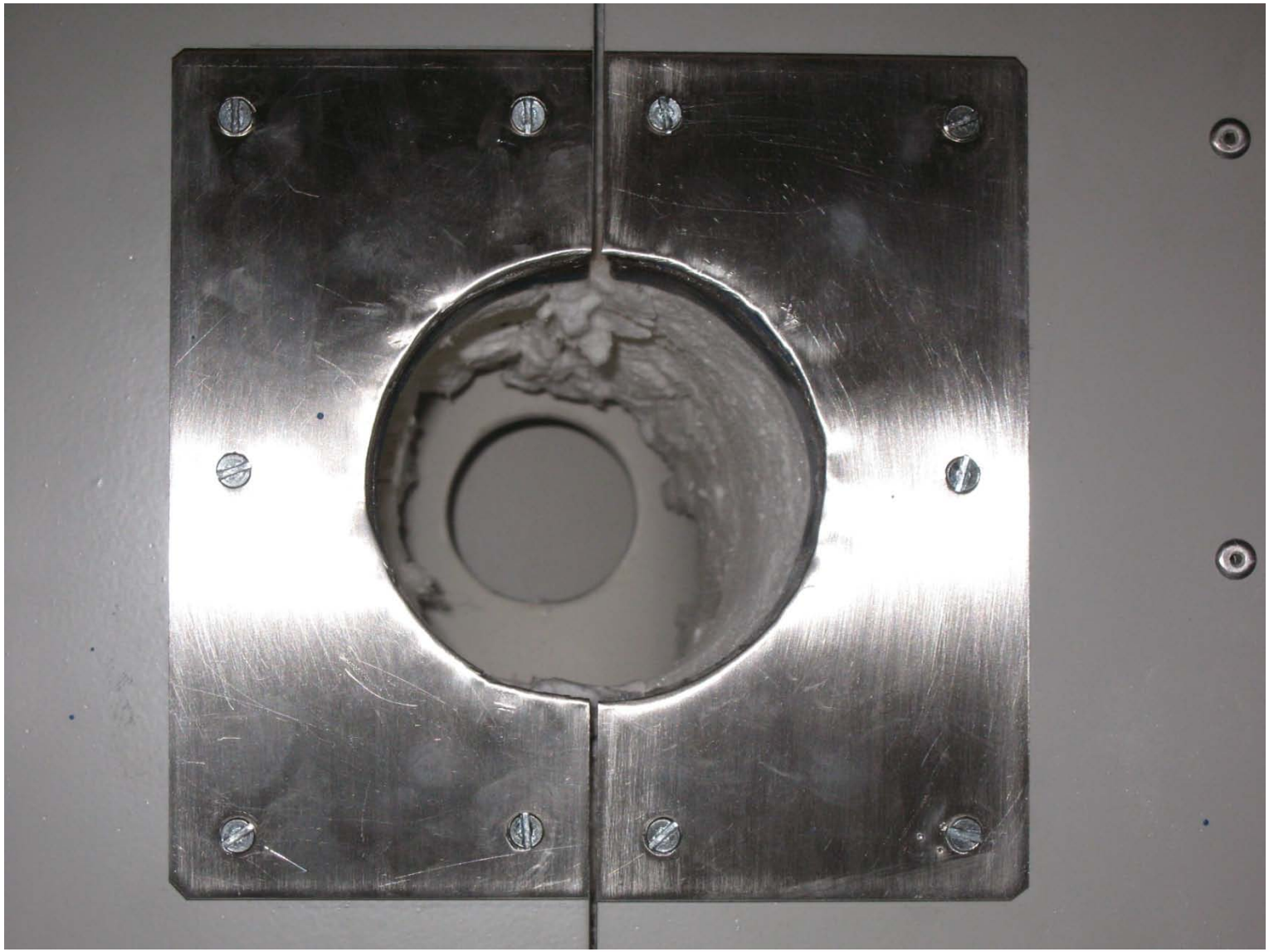








Monica I fuel inlet



Monica I flue gas tube

Monica I flue gas sampling outlet

Monica I view glass

The instrumentation

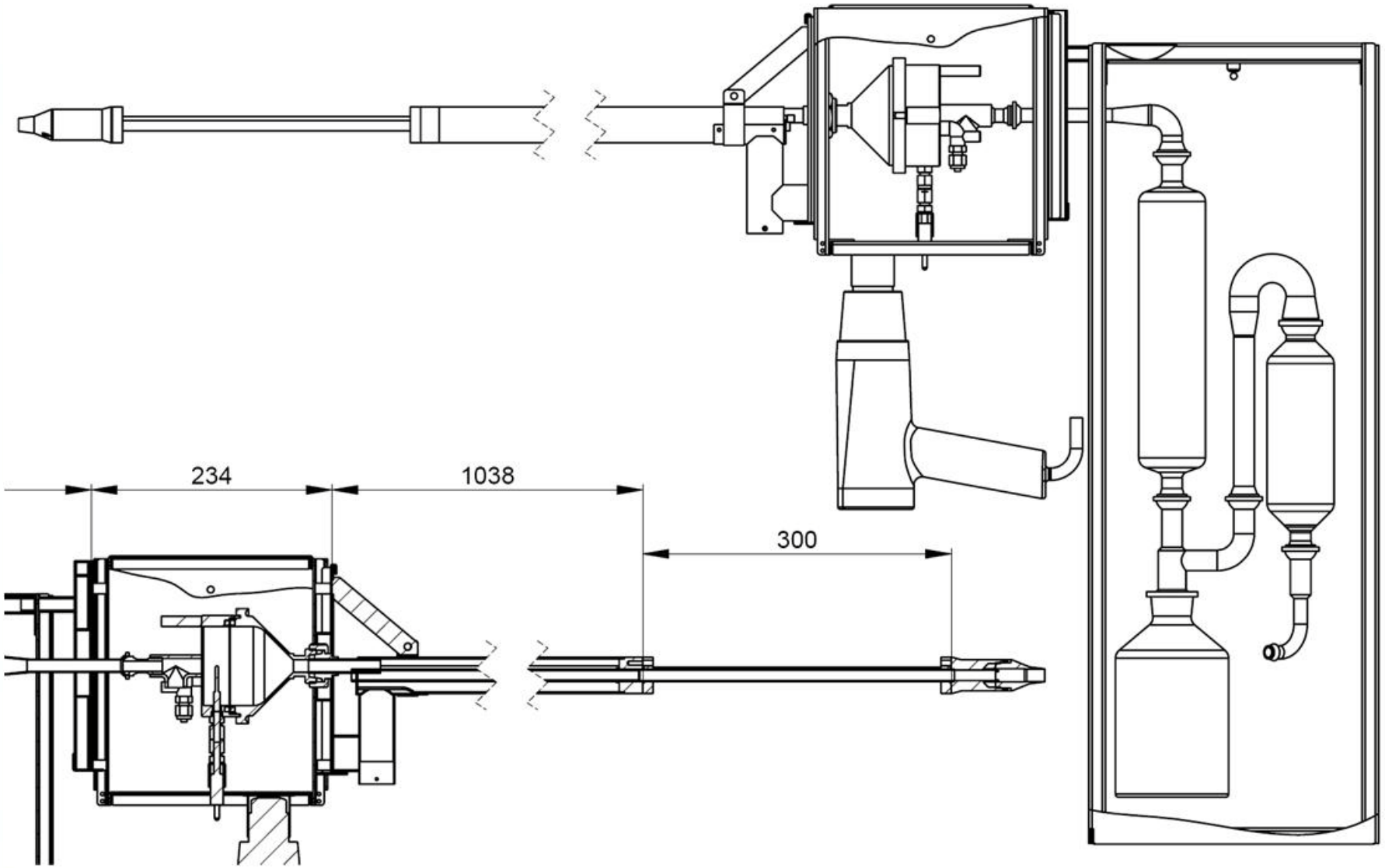
- Fuel feeding speed
- Grate rotating blades speed
- Flow controllers
- Temperatures
- Pressure

The analysis possibilities

- FTIR
- GC
- Multi-species gas analyzer
- Conventional gas analyzers
- ELPI
- Heated filter

Impactor

Heated filter



Fuels

Wood pellets

Demolition wood pellets

Coffee waste pellets

Pellets, 50/50 Wood/Demolition wood

Fuels

Wood pellets (milled)

Demolition wood (milled)

Coffee waste (milled)

Glossy paper (shredded)

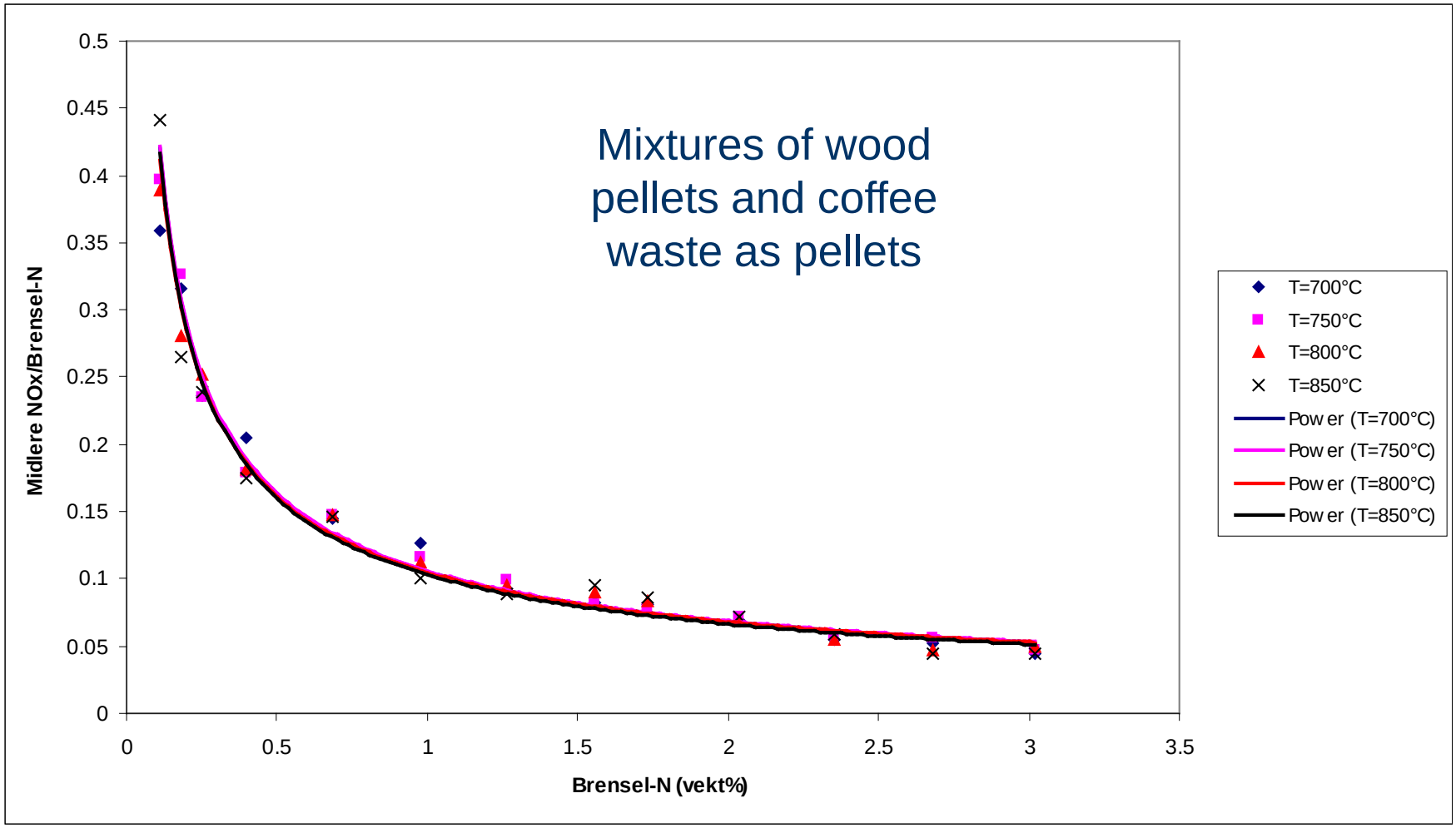
Experiments

- Emissions, e.g. NOx
- Particle size distribution and composition
- Additives effects, e.g. gypsum
- Fuel particle size effects, e.g. pellets versus shredded/milled
- Fuel composition effects
- Temperature effects
- Excess air ratio effects
- Staging effects
- Oxidant composition effects

- Pyrolysis
- Gasification

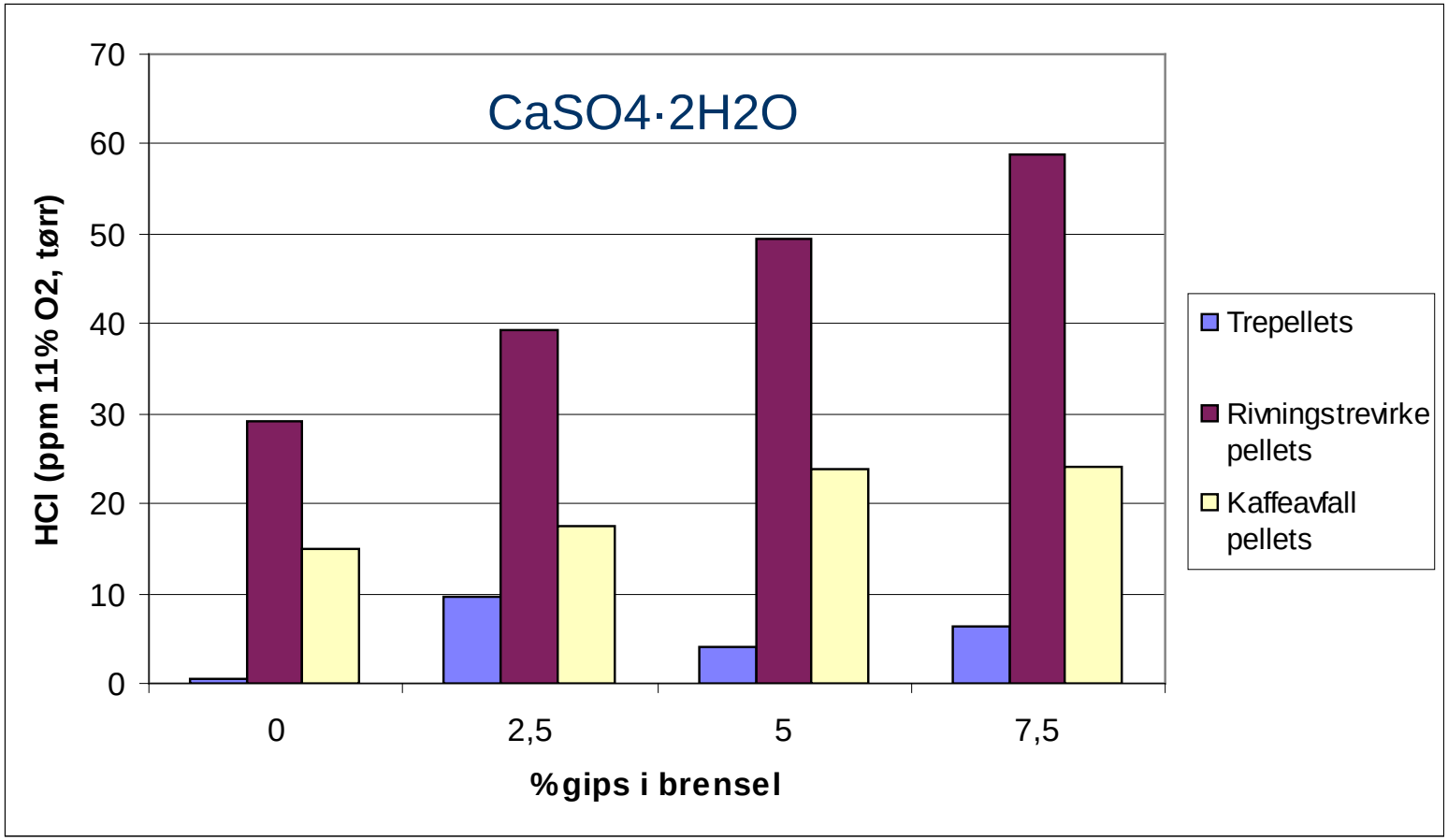
- Macro-TGA

Examples of results



Figur 1 Brenselnitrogen konvertering til NO_x

Examples of results



Figur 1 HCl-utslipp i forhold til gipsmengde i brenslene

Elementsammensetning (vekt%, tørr askefri basis) for brenslene

Brensel	C	H	O	N	S	Cl
Trepellets	50,33	6,21	pd	0,11	<0,02	0,020
Rivningsvirke	49,29	6,08	pd	0,38	0,089	0,033
Kaffeavfall	51,33	6,79	pd	3,02	0,21	0,055

pd: per differanse

Examples of results

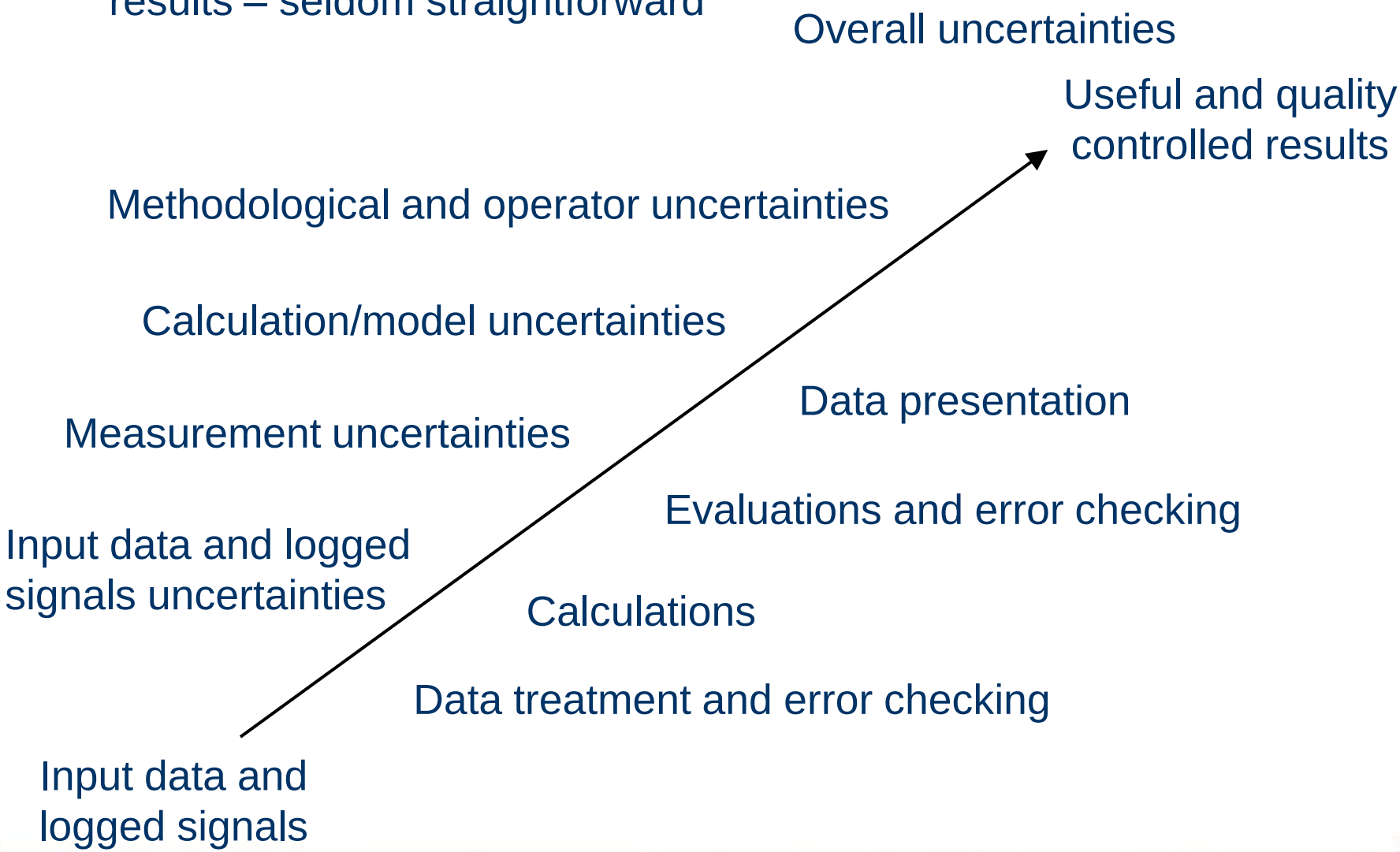
Wood pellets

Wood pellets milled

Fuel preparation effects – wood pellets versus wood pellets milled (FTIR).

Data treatment

- From input data and logged signals to useful and quality controlled results – seldom straightforward



Experiments to be run in the biofuelsGS course

- Combustion with air
- Wood pellets & straw pellets as fuels
- Two temperature levels
- A range of excess air ratios
- Gas analysis with portable FTIR and multi-species conventional analyzer

Wood stove	Heated particle filter	Multi-fuel reactor
Fuel 1&2	Impactor	Fuel 3&4

Data treatment of biofuelsGS experiments

- Convert the raw data into useful and quality controlled results using pre-prepared Excel worksheet (explanation/theory and demonstration on Thursday)

- Extract the following key data for each fuel
  - Burning rate
  - Excess air ratio
  - Emissions levels of NOx, N2O, SO2 and HCl
  - Conversion factors for fuel N, S and Cl
  - Emission levels of NOx as a function of excess air ratio
  - Axial temperature profile in the reactor at each experimental condition

- Compare the above data for the two fuels

- Suggest explanations for differences in the results

- Discuss within your group: How would you design an experimental setup for improved constant operating conditions?