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Experience with Operation of Multi-Stage (Two-Stage) Fixed-Bed Gasifiers in the Czech and Slovak Republic

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Introduction to staged gasification

Advantage of staged gasification:

-increase of cool gas efficiency (η_{ce}>85%)

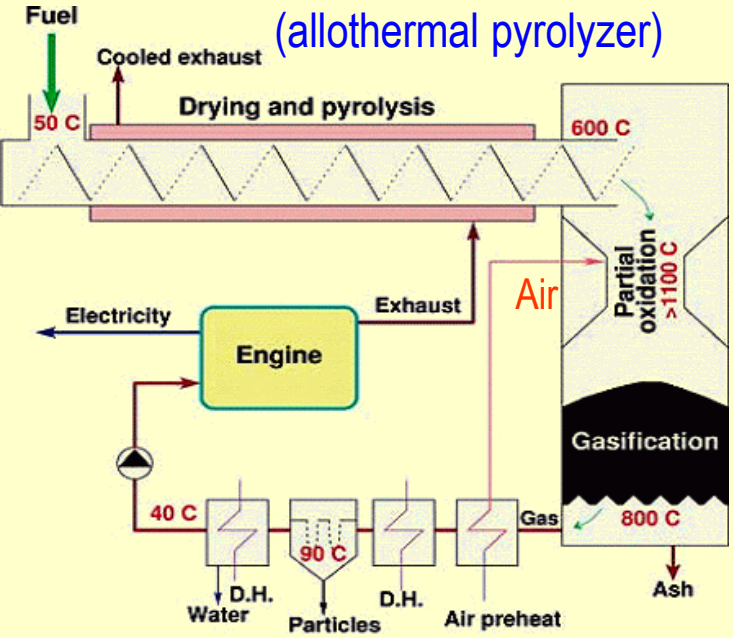
-decrease of tar content on safe level (IC motor, **< 0,1 g/m^3**)

-better gas quality

-better process parameters control and heat management

Viking gasifier concept

(allothermal pyrolyzer)



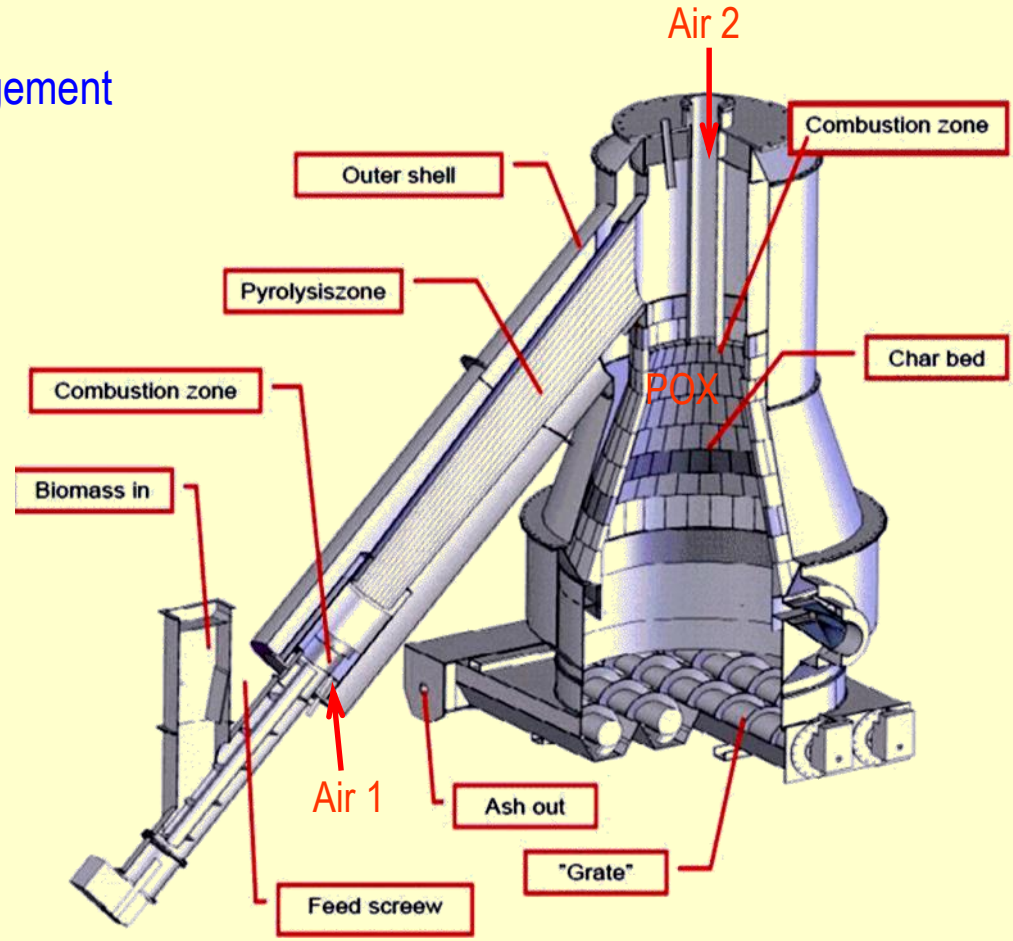
75kW$_t$ DTU, 2000, DK

200 kW$_e$ Hadsund, Weiss A/S, 2007, DK

500 kW$_e$ Hillerød, Weiss A/S, 2010-2013, DK

TK Energy AS concept

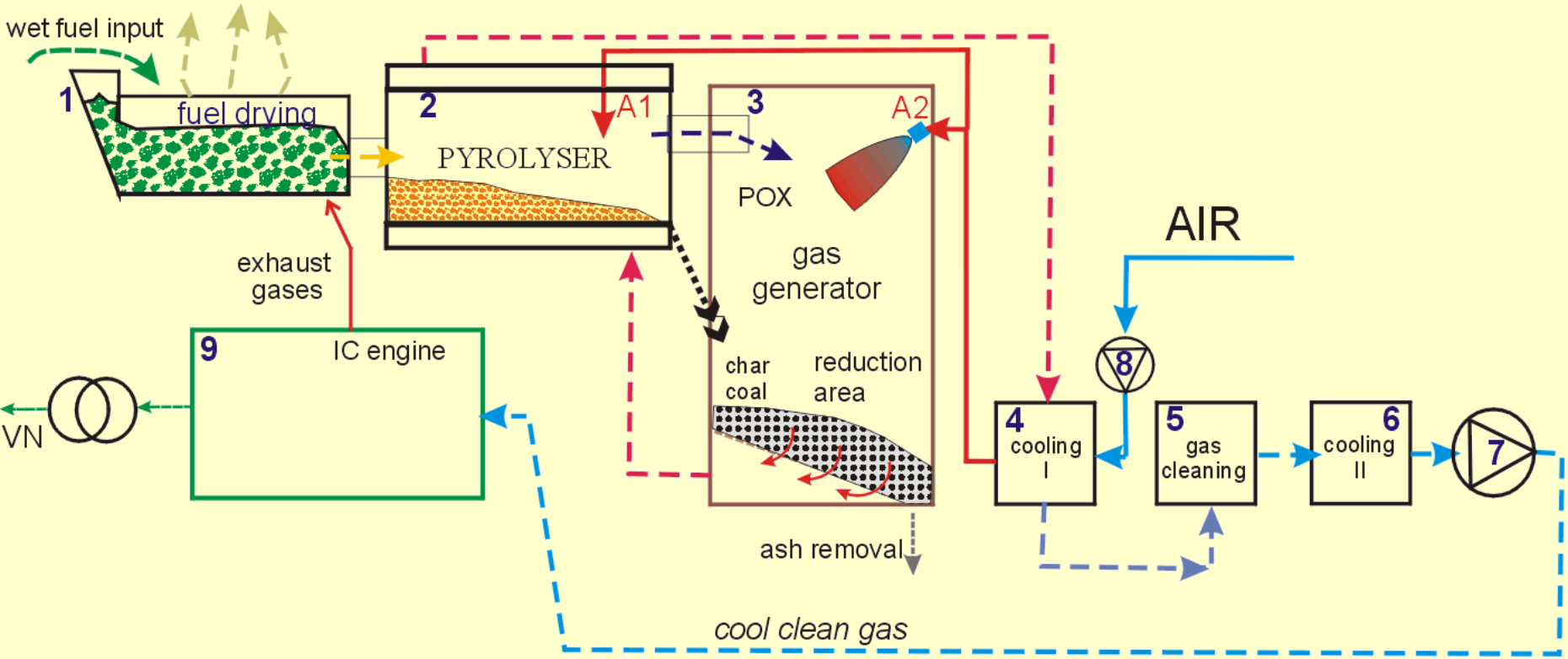
(autothermal pyrolyser,"twin-fire")



700 kW$_e$, Gjol, 2006, DK (only planned)

KIENER Karl, Process and plant for the gasification of solid fuel. Patent. C10J 3/66 [WO 81/00112] 4.Juli.1979/ 5.Juli.1980.

Two-stage gasifier, TARPO concept



Simplified diagram of the TARPO process

- **Prototype of Two Stage generator,200kW$_e$(GP200), TARPO Ltd. Knezeves,**
  construction in 2011, launched in March 2012, GP200 replaced the older type of co-current gen. GP300
- **Reconstruction and extension of power plants for biomass (2011),** Odry (2x500kW$_e$)
  start of the operation (4th quarter 2012), trial operation (2013), modification of auxiliary equipment (solid particles collection system for HT filter, reactor grate modification, 2013 replacement of POX chamber)

Picek et al, Design and commercial application of two-stage fixed bed gasifier in Czech Republic, 6th IFC on IGCC&XtLT., 19-22 May 2014

Two-stage gasifiers in Czech and Slovak Republic

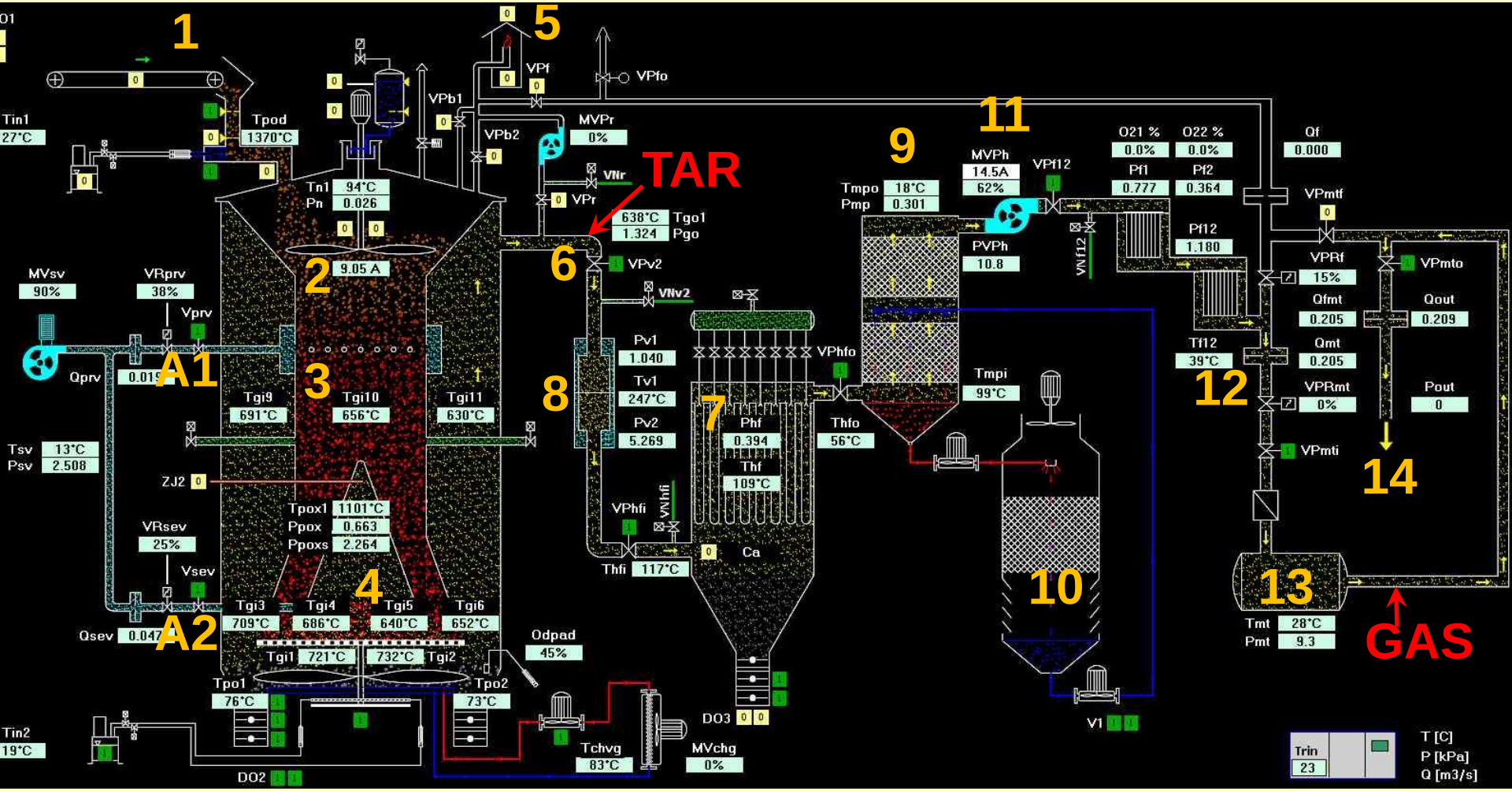
Location	Start of operation	IC engine	Power	Gas cleaning	Current status
1. Kněževes (CZ)	2012, GP200 [1)]	ČKD, 2x6S160	200 kW_e	ceramic candle, water washing/cooling	from 2014 out of permanent operation
2. Odry (CZ)	2013, 2xGP500 [1)]	Jenbacher, 2xJ316	2x500 kW_e	ceramic candle, water washing/cooling	operation with lower output: 2x400 kW_e
3. Olešnice (CZ)	2014/15, GP200XL [1)]	ČKD, 2x6S160	200 kW_e	bag filter, water washing	transformed to twin-fire
4. Handlová (SK)	2014, 2xGP750 [2)]	Guascor, FBLD560 FBLD480	570 kW_e 430 kW_e	bag filter/ceramic candle, water washing	in operation from 4/2015
5. Dobříš (CZ)	2015, 1xGP750 [2)]	Guascor, FBLD560	650 kW_e	bag filter, water washing	in operation for six months, now being transformed to twin-fire
6. Kozomín (CZ)	2014, 5xGP750 [2)]	Jenbacher, 3xJ320	2,1 MW_e,	bag filter/ceramic candle, water washing	pilot operation of five GP750 units

[1)] preheated air was used for gasification [2)] generator has an increased pyrolyser surface area

Kozomín plant (BOR Biotechnology Inc.) parameters

Gas generator	**GP750**
Number of units	5
Maximum power output (good quality fuel)	2500 (3000 kW_t)
Temperature in pyrolysis chamber	500-650°C
Temperature in POX chamber	1000-1200°C (1100°C)
Exit temperature of the gas from the reduction zone	<800°C
Calorific value of gas (LHV)	5,5-6,5 MJ/m^3
Cogeneration unit (engine with el. generators)	
Number of units	3
Manufacturer	Jenbacher AG (GE)
Type	J320 GS (LEANOX)
Number of cylinders/capacity	20/60dm^3
Rated el. Power, max.	**730 kW_e**
flue gas catalyst (CO)	**yes**
Fuel	
Consumption of wood chips (abs. dry)	550 kg/h
Chip size	6-50 mm
Ash content (dry basis)	< 3 % mass
Maximal moisture content, before drying	50 %
Moisture content, after drying	<10 hm. (2-6%)
Specific fuel consumption (abs. dry)	~ 0,7 kg/kWh_{el}
Specific el. output	~ 1,43 kWh_{el}/kg
Char	
Production rate	15-55 kg/h
Ash content in char	10-50% mass (25-30%)

Power plant Kozomín (Handlová, Dobříš), original flowsheet

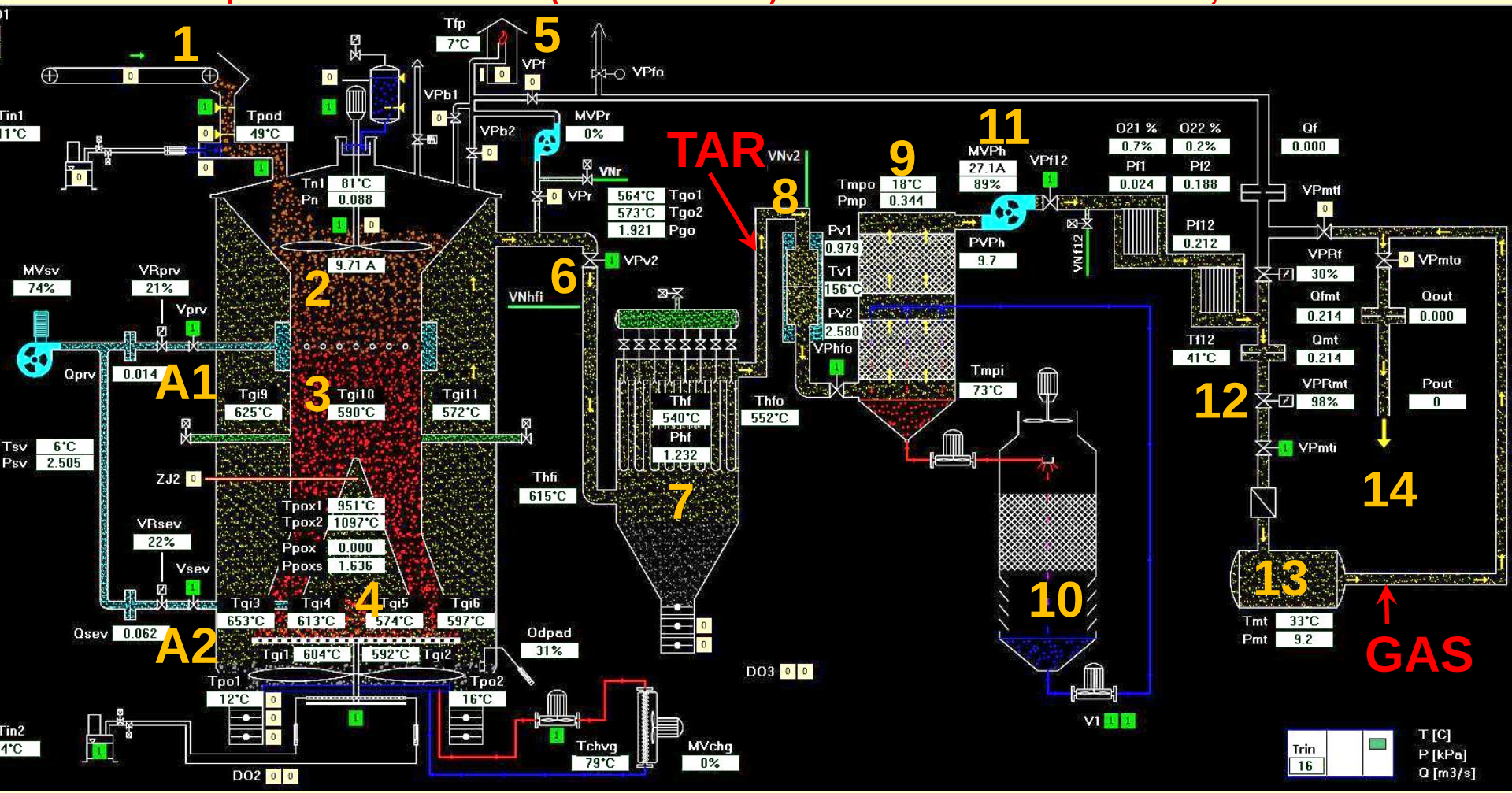


1 - entry of the fuel into the GP750, 2 - allothermal pyrolysis section, 3 - autothermal pyrolysis section, 4 - POX section, 5 - combustion flare, 6 - gas output, 7 - bag filter, 8 - heat exchangers (gas/water), 9 - contact water cooling, 10 - cooling tower, 11 - gas blower, 12 - gas flow measurement , 13 - mix tank, 14 - pipe to IC motor.

A1-primary air inlet, A2- secondary air supply

GAS - point for gas quality sampling (on-line, off-line), TAR - point for gas sampling according to Tar Protocol

Power plant Kozomín (Handlová) after reconstruction, flowsheet



1 - entry of fuel into the GP750, 2 - allothermal pyrolysis section, 3 - autothermal pyrolysis section, 4 - POX section, 5 - combustion flare, 6 - gas output, 7 - hot filters (CERAFIL XS 3000), 8 - heat exchangers (gas/water), 9 - contact water cooling, 10 - cooling tower, 11 - gas blower, 12 - gas flow measurement , 13 - mix tank, 14 - pipe to IC motor

A1 - primary air inlet, A2 - secondary air supply

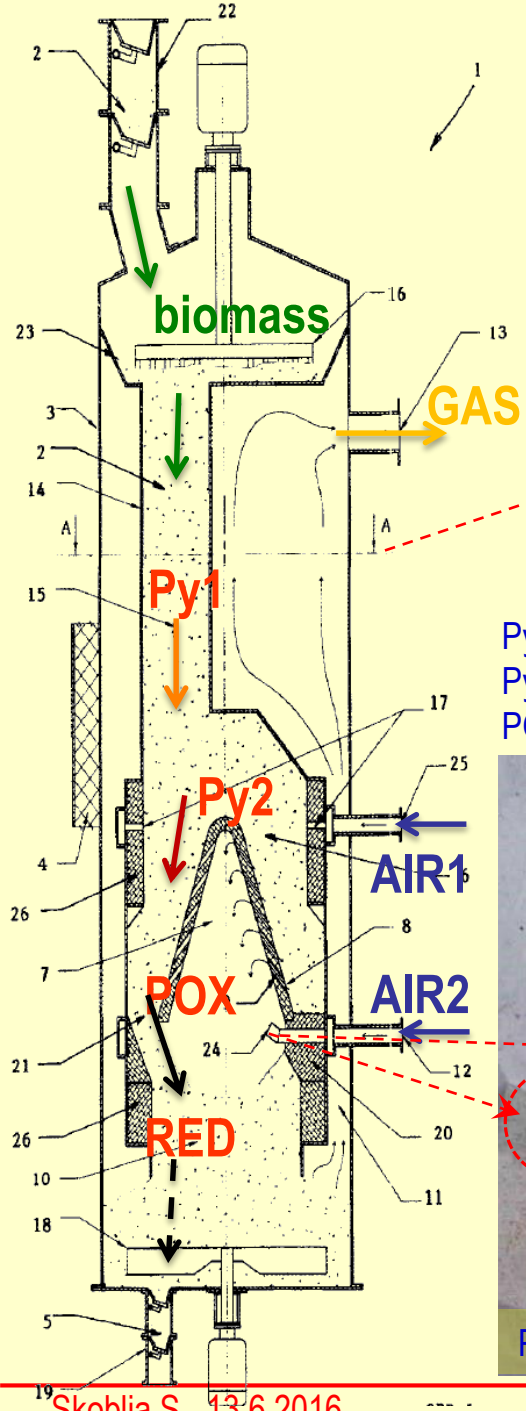
GAS - point for gas quality sampling (on-line, off-line), TAR-point for gas sampling according to Tar Protocol.

Generators hall (BOR Biotechnology Inc.)

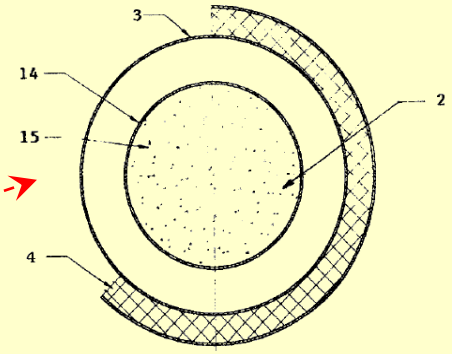
Generators hall (BOR Biotechnology, Inc.)

Simple description of the GP750

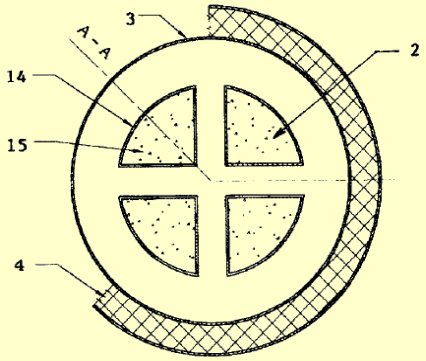
pyrolysis chamber (Py1)



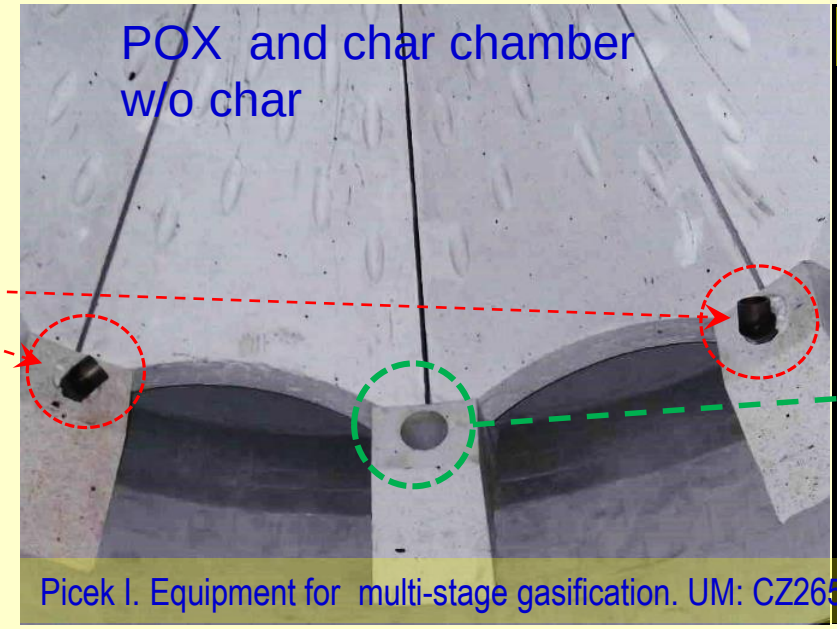
GP200,GP500

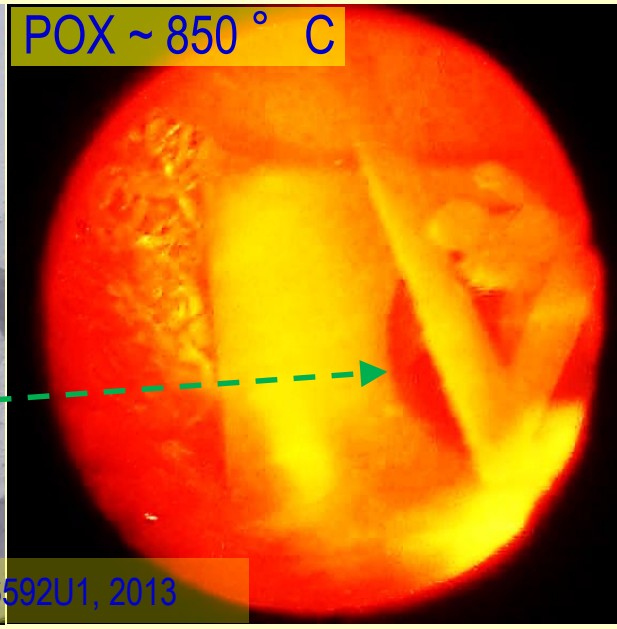


GP750



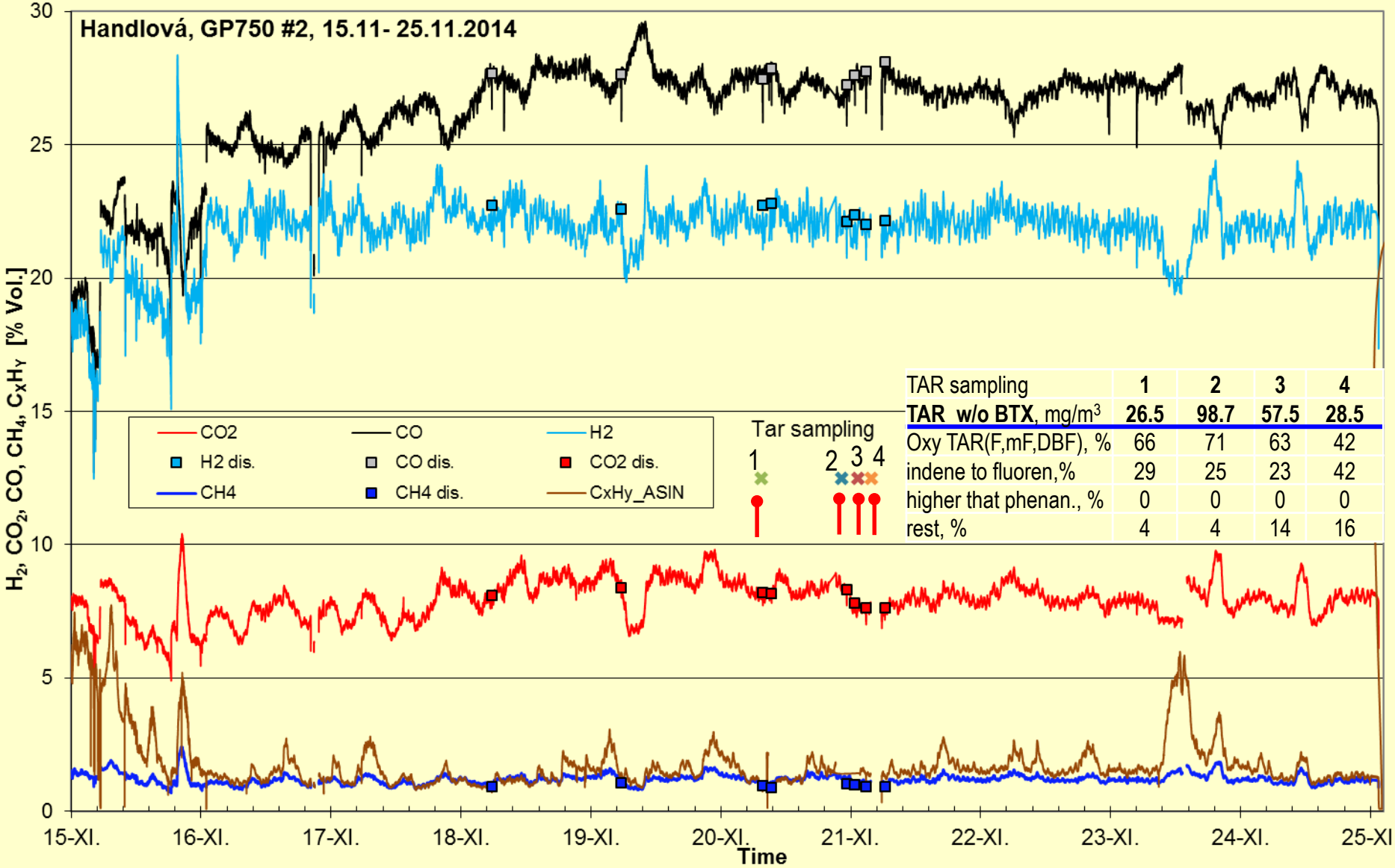
Py1	allothermal pyrolysis chamber	RED	char reduction zone
Py2	autothermal pyrolysis chamber	AIR1	primary air
POX	Partial oxidation zone	AIR2	secondary air





Picek I. Equipment for multi-stage gasification. UM: CZ26592U1, 2013

Gas composition, Handlová (SK), 2014

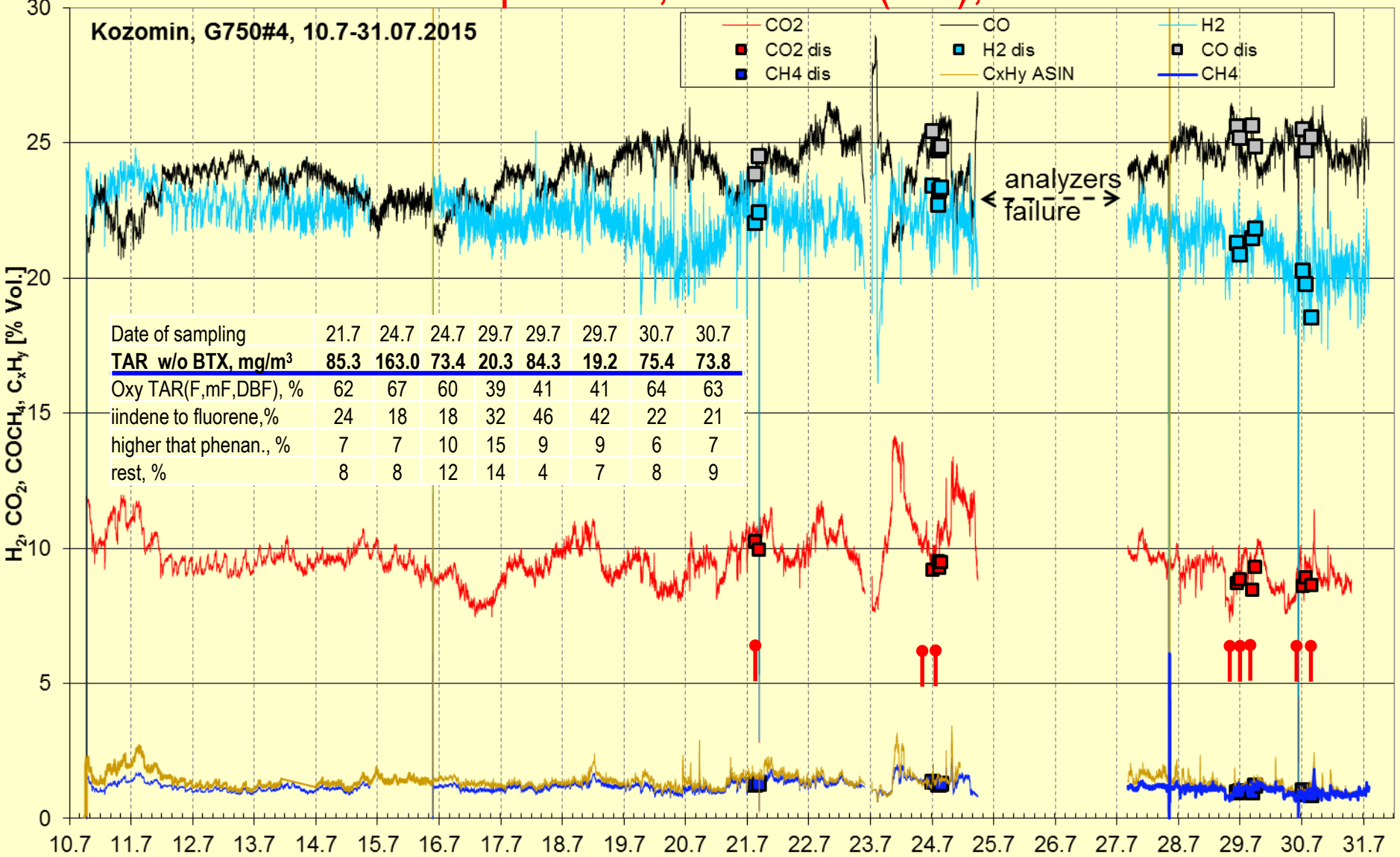


TAR sampling	1	2	3	4
TAR w/o BTX, mg/m³	**26.5**	**98.7**	**57.5**	**28.5**
Oxy TAR(F,mF,DBF), %	66	71	63	42
indene to fluoren,%	29	25	23	42
higher that phenan., %	0	0	0	0
rest, %	4	4	14	16

Dust removal: **fabric bag filters**, **110-120°C** IC motors: Guascor, FBLD560,(56l, V16)

Final gas *treatment:* *water washing/cooling tower*

Gas composition, Kozomín (ČR), 2015



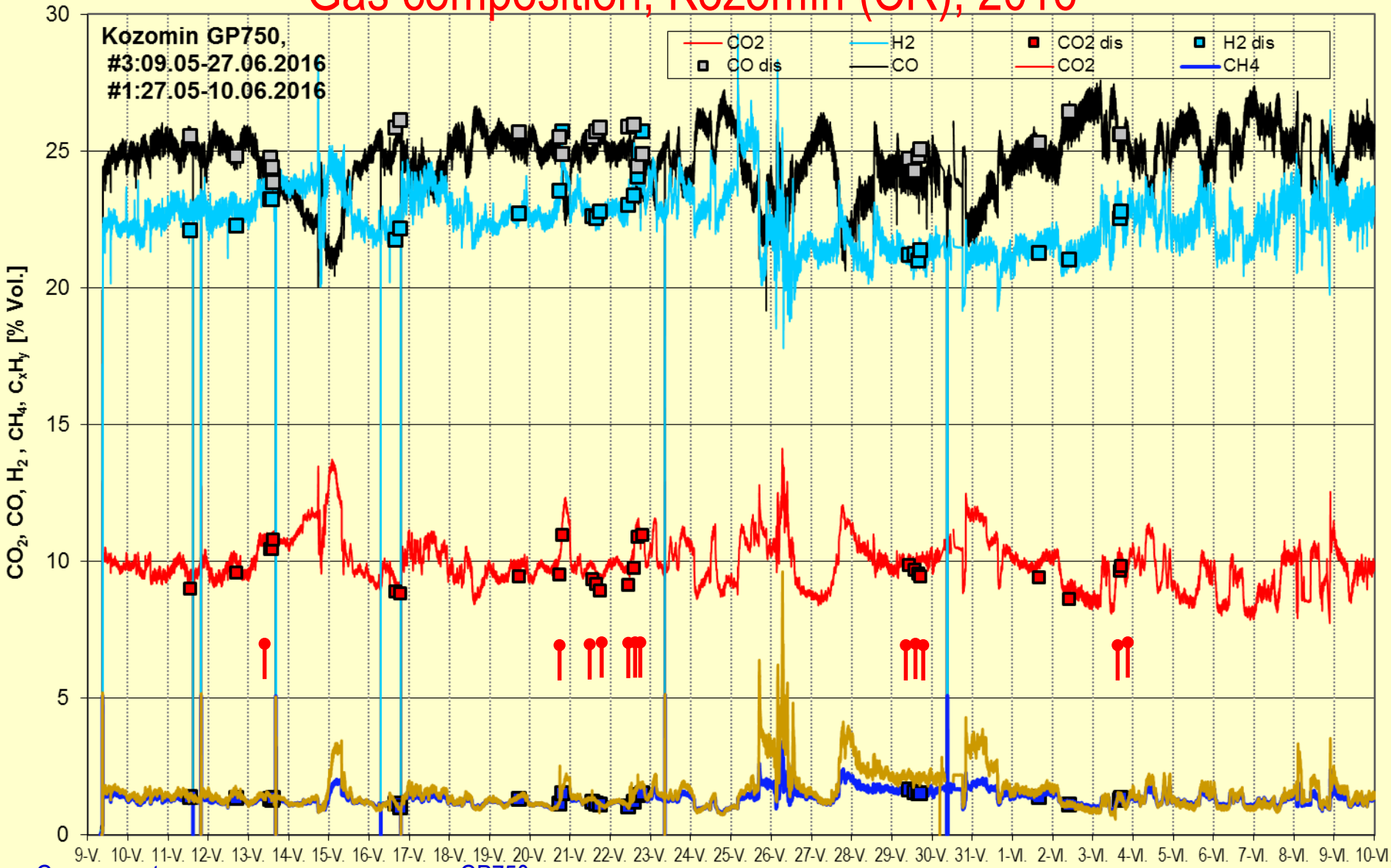
Date of sampling	21.7	24.7	24.7	29.7	29.7	29.7	30.7	30.7
TAR w/o BTX, mg/m³	**85.3**	**163.0**	**73.4**	**20.3**	**84.3**	**19.2**	**75.4**	**73.8**
Oxy TAR(F,mF,DBF), %	62	67	60	39	41	41	64	63
iindene to fluorene,%	24	18	18	32	46	42	22	21
higher that phenan., %	7	7	10	15	9	9	6	7
rest, %	8	8	12	14	4	7	8	9

Gas generator: GP750, (G4) IC motors: Jenbacher J320 (550-630kW$_e$)

Dust removal: **Hot FILTR, 500-600°C**

Final gas *treatment:* *water washing/cooling tower*

Gas composition, Kozomín (ČR), 2016



Gas generator: GP750

Dust removal: **Hot FILTR, 500-600°C**

Final gas *treatment:* *water washing/cooling tower*

IC motors: Jenbacher J320 (550-630kW$_e$)

Fuel properties and their effects on generator operation

Proximate and ultimate analysis of selected fuels




fuel properties	Handlová, 2014	Kozomín, 2015	Kozomín*), 2016	Kozomín, 2016
moisture, W^a	5.00	14.00	2.61	2.89
ash, A^d	1.08	2.78	1.03	0.98
volatile matter, V^d	79.75	78.80	78.84	81.10
fixed carbon, Fc^d	19.17	18.42	20.14	17.92
Q_i^a	16.94	14.72	16.71	17.23
Q_i^{daf}	18.16	18.02	17.40	17.99
ultimate analysis, ^{d}				
C	49.58	50.28	48.62	48.40
H	6.30	6.15	5.88	6.08
N	0.50	0.27	0.23	0.19
O	42.52	40.48	44.24	44.34
S	0.02	0.04	0.01	0.01

*)chips stored for long period in the open air

Composition of gas from co-current and staged gasifier

	BOSS Imbert[2] 100kW$_e$	Co-current GP300[2]	Viking DTU 75 kW$_t$	GP200[2]	GP500[2]	GP750
moisture, % hm.	<10	<10	35-45	<10	<10	<10
CO	25,5	24,6	19,6	26,7	25,0	25,3
H_2	17,2	16,4	30,5	23,0	22,3	22,7
CH_4	***3,0***	***2,2***	***1,2***	***1,1***	***2.00***	***1,3***
CO_2	9,6	9,6	15,4	8.00	9,4	9,7
N_2(+Ar)	***43,5***	***46,1***	***33,2***	***40,6***	***41,1***	***40,9***
Other	1,2	1,1	0,1	0,6	0,2	0,1
Tar, mg/m^3	**1000-2000[1]**	**1300-2000[1]**	**<5**	**0,5-2,0[1]**	**5,0-40[1]**	**20-200[1]**
Q_i (15/15 °C) MJ/m^3	6,3	5,7	5,6	5,9	5,9	5,8

[1] Determination of tar was carried out according to Tar Protocol. Given value does not contain toluene, xylenes and benzenes

[2] Air for gasification was preheated.

The POX chamber size for different gasifiers

Type	POX chamber		Volume	Flow*	R. T.*
	D,m	H,m	m^3	m^3/h	s
GP200	1,0	1,1	~0,3	~400	~2,7
GP500	1,6	2,1	~1,5	~900	~6
GP750	2,5	2,3	~4,0	~1400	~10

* Normal condition

Thank you for your attention

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