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Design and commercial application of two-stage fixed bed gasifier in Czech Republic

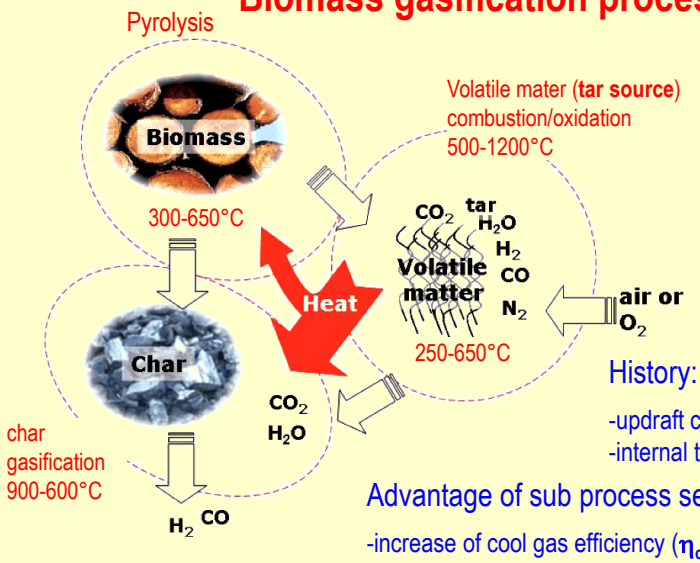
Ivo Picek[1], Siarhei Skoblia[2], Zdenek Beno[2], Michal Pohořely[2,3]

[1] **TARPO ltd**, Kněževes, Czech Republic; tarpo@tarpo.cz;

[2] **ICT Prague**, Czech Republic; skobljas@vscht.cz;

[3] **Institute of Chemical Process Fundamentals ASCR**, Prague, Czech Republic; pohorely@icpf.cas.cz

Biomass gasification process



History:

-updraft charcoal gasifier
-internal tar recycling gasifier

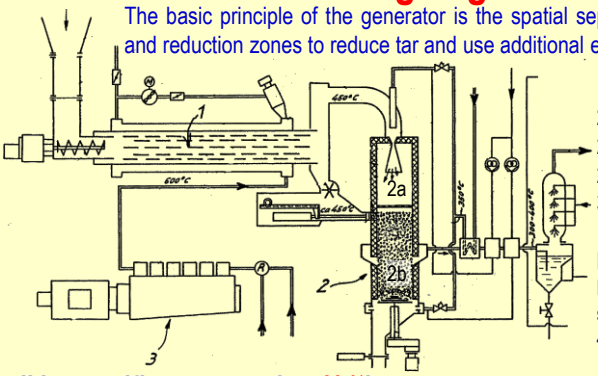
Advantage of sub process separation:

-increase of cool gas efficiency (η_{ce}>85%)
-decrease of tar content on safe level (**< 0,1 g/m^3**)
-better gas quality (higher heating value)
-better process parameters control and heat management

Barrio M. (2002). Experimental investigation of small-scale gasification of woody biomass. Ph. D. Thesis, NTNU.

Staged gasifiers

The basic principle of the generator is the spatial separation pyrolysis zone from oxidation and reduction zones to reduce tar and use additional external heat to increase the efficiency.



1-indirect heating
2-reaction zone with thermal cracker
2a- partial oxidation burner
2b- coke partial combustion part
3- gas engine

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

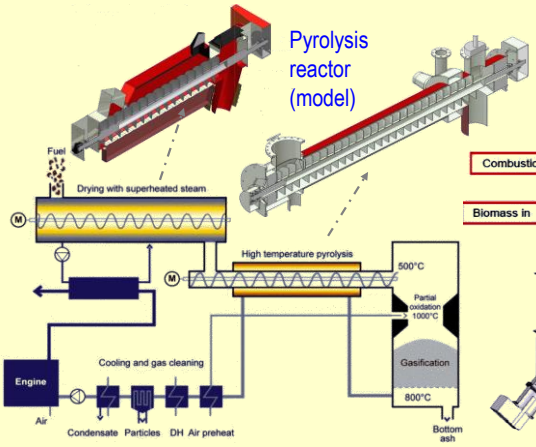
- **Viking gasifier concept (η_{ce}>90 %)**
  - 75 kW_t, (~20kW_e) DTU (DK), 2000
  - 200 kW_e,Hadsund, Weiss A/S, 2007, DK
  - 500 kW_e Hillerød, Weiss A/S, 2010-2013, DK

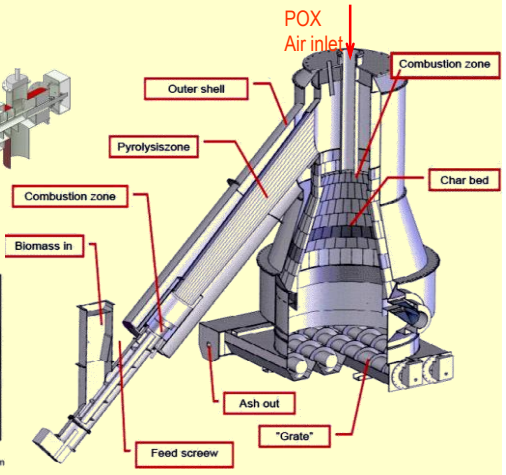
scale up of original concept without major structural re-design is difficult

- **TK Energy A/S, Thomas Koch** (η_{ce}=85 %)

biomass is pyrolysed by heat from PO of part of fuel with air (600°C), PO of volatile matter and reduction on the charcoal
  - 125 kW_e,TK Energi A/S, DK
  - 700 kW_e, Gjol, 2006, DK (only planned)
- **CHOREN Carbo-V** production of **tarfree** gas for F-T synthesis
- **Low-Tar BIG, Low-Temperature Circulating Fluid Bed, FICFB** (concept)

Comparison of staged gasifiers



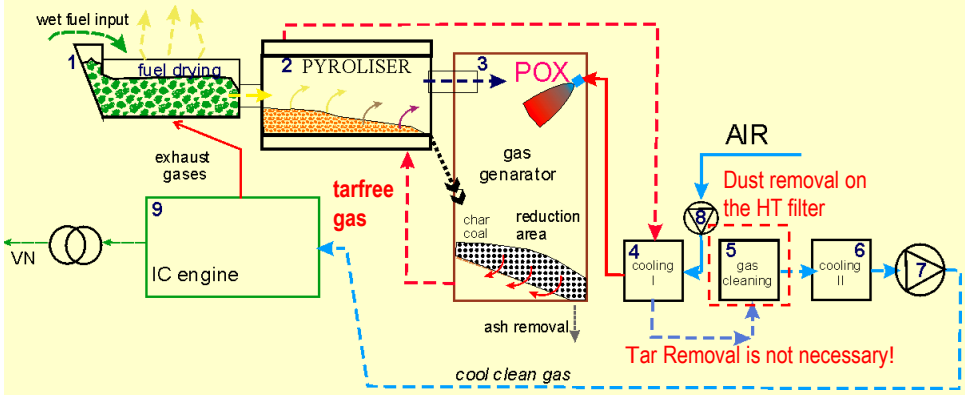


Advanced Viking gasifier concept
500 kW_e Hillerød, Weiss A/S, 2010-2013, DK

TK Energy AS concept
700 kW_e, Gjol, 2006, DK (only planned)

Demonstration of 500kWe Twostage Gasifier, final report, march 2013, WEISS A/S
2-stepgasificationofbiomass, Electric power generation with High efficiency, 2010, WEISS A/S
Koch T., Biomass Gasification with low tar production. Staged gasification,Florianôpolis Brasil June 2007

Two Stages 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 generator GP300
- **Reconstruction and extension of power plants for biomass (2011),** Odry (2x500kW$_e$)
  start of 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)

Two Stages gasifiers in Czech Republic

Location	Start of operation, type	IC motor	Power output
1. Kněževes (CZ)	2012, GP200	ČKD, 2x6S160, 27l, R6	200 kW$_e$
2. Odry (CZ)	2012, 2xGP500	Jenbacher 2xJ316, (48l, V16)	2x500 kW$_e$
3. Olešnice (CZ)	2013, GP200XL	ČKD, 2x6S160, 27l, R6	200 kW$_e$
4. Handlová (SK)	2014, 2xGP750	Guascor, FBLD560, (56l, V16)	2x750 kW$_e$
5. Dobříš (CZ)	2014, 1xGP750	Guascor, FBLD480, (48l, V16)	650 kW$_e$ (+ gas appl.)
6. Kozomín (CZ)	2014, 5xGP750	Jenbacher, 3xJ320, (60l, V20)	2,1 MW$_e$(3x710kW$_e$) 5,1 MW$_t$ (heat appl.)

The efficiency of electricity generation vs. cold gas efficiency

$\eta_t = \eta_{CE} * \eta_{CU}$

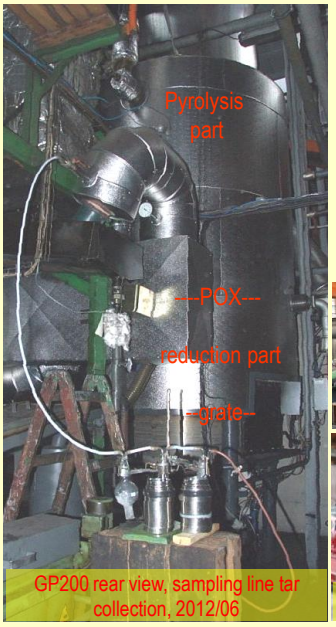
η_{CE} - cold gas efficiency which takes into account only the chemical energy stored in the gas

η_{CU} - cogeneration unit efficiency (IC motor+ el. gen.)

Type of generation	cold gas efficiency η_{CE}, %	gas to electricity efficiency (), η_{cu}, %	Overall el. efficiency η_t, %	Inst. costs thousd.EUR /kW$_e$
1. power plant with steam turbine (11 MW$_e$) Green boiler (Zeleny kotel, 33 MW$_t$),2010, Plzeň	-	-	**27,6**	3.2
2. downdraft „Imbert" gasifier (100 kW$_e$) Boss engineering ltd,Louka,2005, Staré město,2009	65	max. 30 liaz M1.2,12dm^3,6 C	**max. 19,5**	2.4
3. downdraft gasifier„GP300" with adv. heat recovery (200 kW$_e$) Tarpo ltd, Kněževes, 2009	75	~ 32 ČKD 6S160,27 dm^3,6C	**~ 24**	2.4-2.8
4. Prototype of Two Stage gasifier (200kW$_e$) Tarpo ltd, Kněževes, 2011/2012	min. 85	**~32** (see 3) **max. 36** (see 5)*	**~ 27,2** **~ 30,6**	3.2-3.6 **3.2-4,0**
5. Two Stage gasifier (2x530kW$_e$) Tarpo ltd, Air Technic s.r.o. Odry, 2012	**~ 90**	**~ 36***	**~ 32,4**	**3.2*** **
6. Model: Two Stage gasifier, 3,5-8 MW$_e$	max. 95	42-44 **	**~ 40**	????

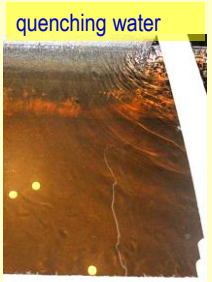
* Jenbacher AB, J316 GC
** Jenbacher, J624* GC with 2 stage turbocharger η_{cu}, = 46,1% 4,35 MW$_e$, J920* GC with 2 stage turbocharger η_{cu},= 48,7%(NG) 9,5MW$_e$
*** The first commercial implementation in CR, Power plant Odry (25 CZK=1 EURO)

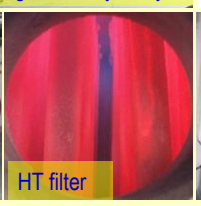
Prototype of Two Stage gasifier, GP200, TARPO ltd. Kneževes



Basic parameters

Gas generator:	GP200, 200kW$_e$, (from march 2012)
Dust removal:	**ceramic candle filters, 390-550°C**
Tar removal (3/2013-disconected):	org. liq. scrubber **60°C**/air reg.at **120°C**
Final gas treatment:	water washing/cooling tower
Gold gas efficiency:	~85 %
Gas to electricity efficiency:	~32 %
Overall el. efficiency:	**~27,2 %**
IC motors S160 ČKD Hořovice,vol	27 dm^3
Cylinder/compression ratio:	6/11.5
Electrical output:	100 kW$_e$



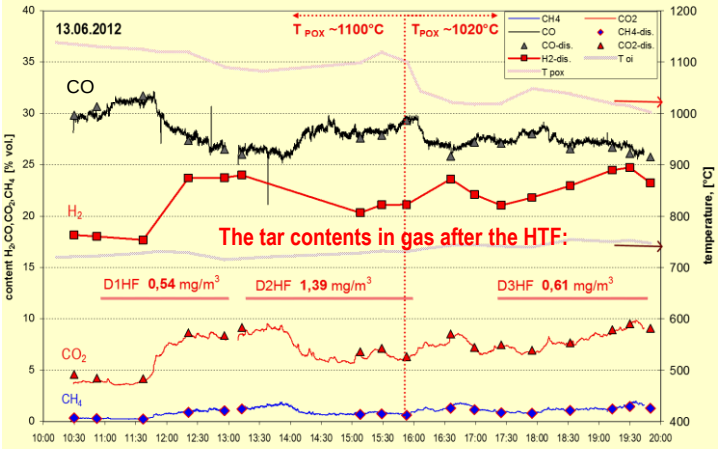


Skoblja S.: Schemes and new developments in combinations of gasification with fuel gas cleaning for power generation in gas piston engines and gas turbines, Fecundus Interna-tional Workshop, Prague, Czech Republic, June 12-14, 2013.

Commercial unit GP200XL,200kW$_e$ Olesnice, 2013

Prototype of Two Stage gasifier, 200kW$_e$, gas composition

Selected data record



Average gas composition

components	Conc. % vol.
O_2 in sample	0.84
CO_2	7.72
H_2	22.37
CO	27.31
CH_4	0.97
N_2	41.14
Ar	0.48
ethane	0.0017
ethylene	0.0018
acethylene	0.0002
propene	-
benzene	0.0005
toluene	0.00003
Other	0.0002
Sum	100
LHV(15/15C), MJ/m^3	5.89
LHV (0/0C), MJ/m^3	6.21

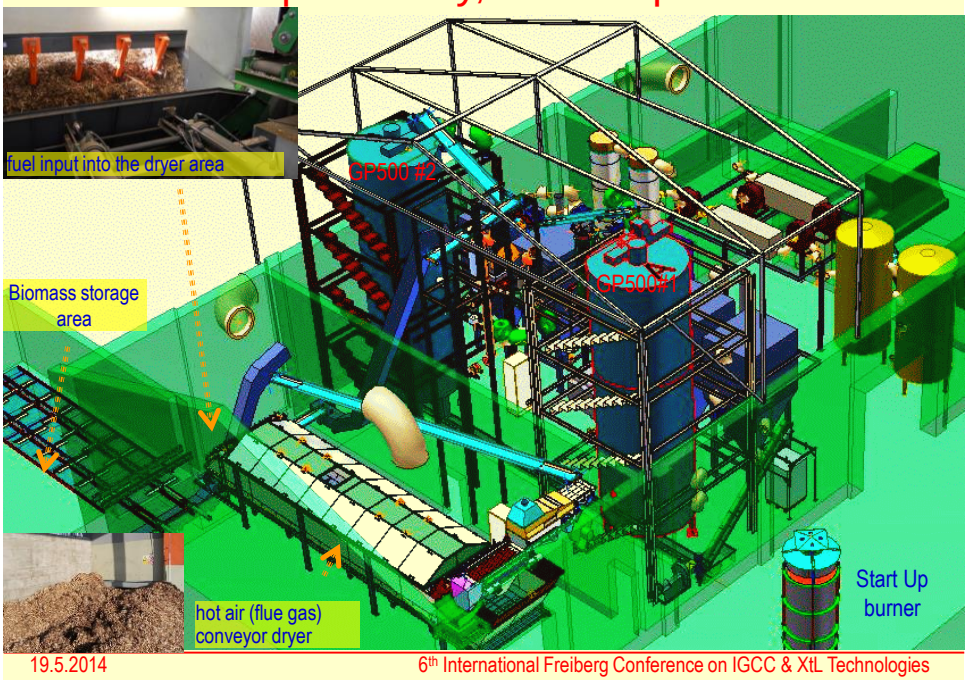
POX temperature: (1000 - 1150°C). Raw gas from generator contain minimum amount of tar and hydrocarbons (BTX).

The basic parameters of the Power plant, Odry, 2012

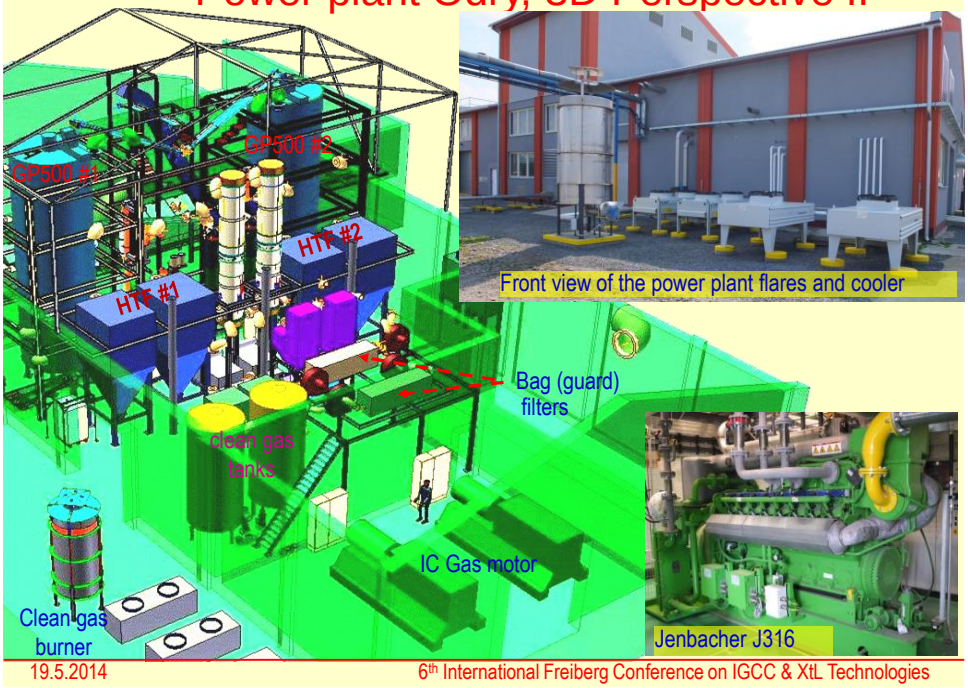
Number of units:	2, GP500
Gas generator	
maximum power output (good quality fuel)	1700 (2500 kW_t)
temperature in pyrolysis chamber	500-650°C
temperature in POX chamber	1000-1100°C (1250°C)
exit temperature of the reducing zone	<750°C
Calorific value of gas (LHV)	5,5-6,5 MJ/m^3
Cogeneration unit (engine with el. generators)	
Manufacturer	Jenbacher AG (GE)
Type	J316 GS (LEANOX)
Number of cylinders/capacity	16/48dm^3
Rated el. Power	**500 (550) kW_e**
Fuel	
Consumption of wood chips (abs. dry)	360 (400) kg/hod
Chip size	20 až 80 mm (1-50mm)
Ash content (dry basis)	< 2 % mass (<5 mass)
Maximal moisture content, before drying	50 %
Moisture content, after drying	<10 hm. (20 hm. %)
The waste heat of cooling water (80°-90°C)	**650** kW_t
The electrical efficiency	**min. 32%**
Specific fuel consumption (abs. dry)	**~ 0,7 kg/kWh_{el}**
Specific el. output	**~ 1,43 kWh_{el}/kg**

GP500 #1, November 2012

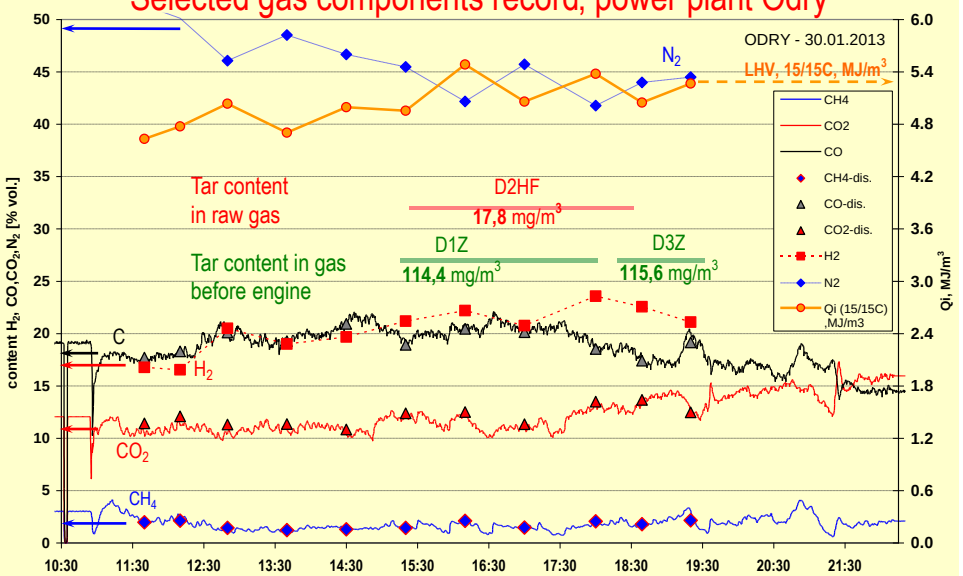
Power plant Odry, 3D Perspective I



Power plant Odry, 3D Perspective II



Selected gas components record, power plant Odry

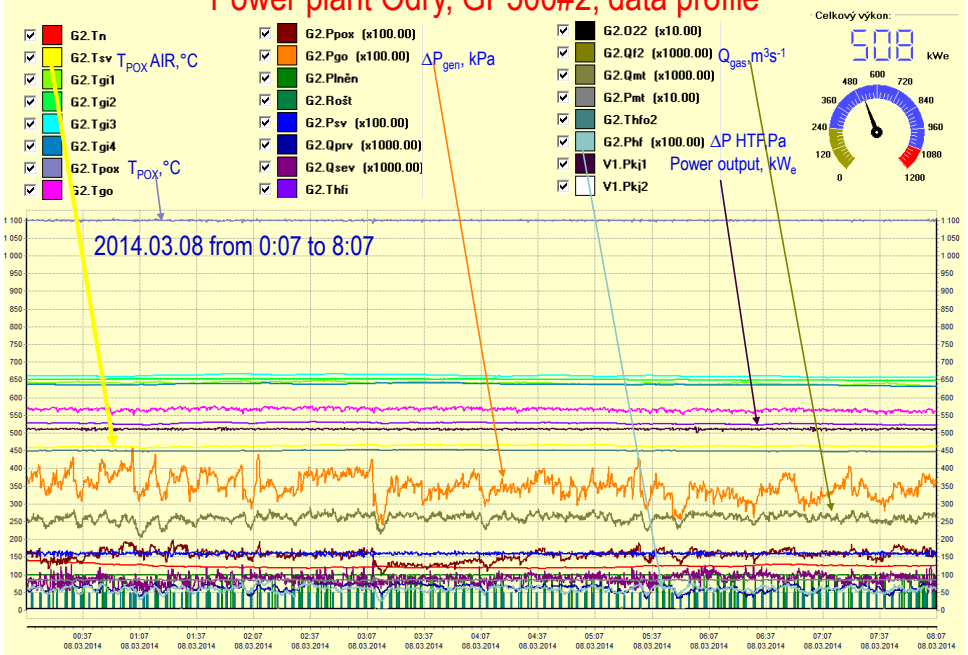


engine power output: 300 kW_e

Temperatures in POX chamber around 1000°C allow to produce gas with low-tar and hydrocarbons contents (BTX).

Tar composition (% mass.): 80-90% naphthalene, 3% 1-MN+2-MN, 3-4% acenaphthene, < 1% fenatren + anthracene

Power plant Odry, GP500#2, data profile

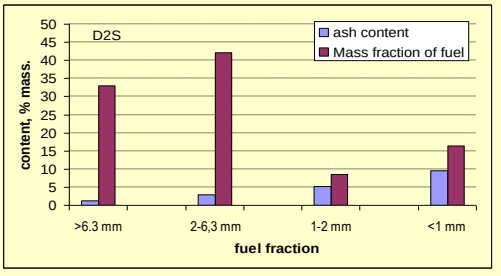


Properties of fuel used in Power plant, Odry

Proximate and ultimate fuel composition (D2S)

fuel properties	value	a	d
moisture,W	% mass.	30.11	0.00
ash, A	% mass.	2.54	3.64
volatile,V	% mass.	54.39	77.82
fixed carbon, Fc	% mass.	12.96	18.54
Q_s	$MJ.kg^{-1}$	13.73	19.64
Q_i	$MJ.kg^{-1}$	12.85	18.39
C	% mass.		49.05
H	% mass.		6.03
N	% mass.		0.26
O	% mass.		41.02

Fuel size distribution and ash content



Power plant, Kozomín CZ, 2014


Reactors hall, 5xGP750, March, 2014

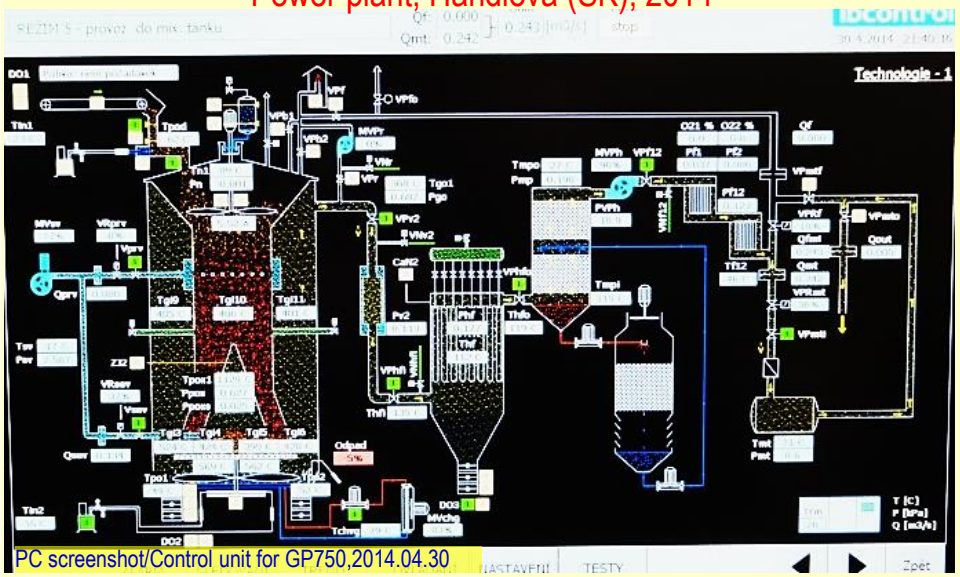

Steam generator, March, 2014


motors hall, J320, December, 2013

Gas generator: 5 x GP750, (3x710kW$_e$,+4,2MW$_t$)
Dust removal: **fabric bag filters**, **120-150°C**
Final gas treatment: water washing/cooling tower

IC motors: Jenbacher, 3xJ320

Power plant, Handlová (SK), 2014



PC screenshot/Control unit for GP750,2014.04.30

Gas generator: 2 x GP750, (2x750kW$_e$)
Dust removal: **fabric bag filters**, **120-150°C**
Final gas treatment: water washing/cooling tower

IC motors: Guascor, FBLD560,(56l, V16)

Power plant, Handlová (SK)

Thank you for your attention

Contacts:

Ivo Picek
tarpo@tarpo.cz
+420 776 732 593
TARPO ltd.,
Pražská 346,
Kněževes 270 01
Czech Republic
http://www.tarpo.cz

Siarhei Skoblia
skobljas@vscht.cz
+420 220 444 125
Dept. of Gas, Coke and Air Protection, ICT Prague
Technická 5,
Praha 166 28
Czech Republic