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The negative effects of biomass combustion and co-combustion in small power boilers

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Why does the energy sector has its interest in biomass combustion?

- The increasing importance of renewable energy sources in the UE as a result of the need to lower the emission of CO_2, and the need of lowering the fossil fuels used
- The cheapest way for energy manufacturers to produce „*green energy*"
- The system of „*green certificates"* – as a support for the development of renewable energy (regulations for energy producers).
  This kind of support has been significantly reduced…

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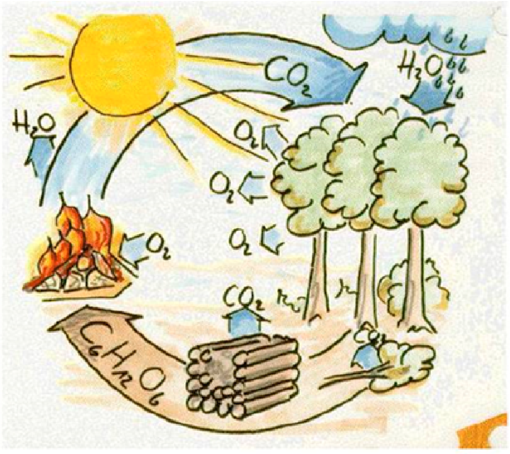
Why does the energy sector has its interest in biomass combustion?

- The use of biomass in power sector is the so-called "zero balance of CO_2 emission"

„zero balance of CO_2 emission" →
CO_2 emissions during combustion of biomass – CO_2 absorption by the biomass during its growth = zero (???)



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Biomas combustion and co-combustion in energetics

- in furnaces of power boilers (stoker boilers, fluidized bed boilers, pulverized coal boilers)

- in furnaces of small heating plants boilers (eg., stoker boilers)



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Gaseous pollutants emitted while biomass combustion and co-combustion

The most important pollutants that are emitted while combustion of biomass (similar like in the case of coal):

- Carbon dioxide - CO_2
- Carbon monoxide - CO
- Nitrogen oxides - NO_x
- Sulfur oxide - SO_2
- Hydrocarbons - C_xH_y
- Chloride and chlorine – HCl and $Cl_{2,}$

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Gaseous pollutants emitted while biomass combustion and co-combustion

as well as:

- Volatile Organic Compounds – VOCs (aldehydes, ketones, alcohols, aromatic hydrocarbons)
- Persistent Organic Pollutants – POPs (Polycyclic Aromatic Hydrocarbons (PAHs)
- total dust and subfractions (PM_{10}, $PM_{2,5}$)

Some of these compounds have been identified as carcinogenic, mutagenic and teratogenic.

- lotne związki organiczne (LZO) – aldehydy (np. Formaldehyd), alkohole, estry, WA (benzen, toulen, ksylen)
- trwałe związki organiczne (TZO) – wielopierścieniowe węglowodory aromatyczne (WWA), dioksyny i furany (PCDDs i PCDFs) i polichlorowane bifenyle,
- pył całkowity (TSP) oraz jego frakcje PM^{10}, $PM^{2,5}$.
W mniejszym stopniu metale ciężkie – raczej tylko niektóre rodzaje biomasy.

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Gaseous pollutants emitted while biomass combustion and co-combustion

Emissions of NO_x, CO and organic pollutants (as PAHs, PCDD and PDF) strictly depends on the combustion technology and fuel characteristics.

It should be noted that biomass combustion in an oven/boiler with outdated design also results in a large emission of toxic pollutants.

High emission of toxic components, due to the low height of chimneys in the residential sector (small bloilers/heating stoves), causes a high concentration of air pollutants at ground level (so-called low-emission). This is dangerous especially in densely populated areas due to direct inhalation of contaminated air by humans and eating contaminated food.

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Low-emission

„Low emissions” - the potential high risk to health and the environment arising from the frequent burning of hazardous waste by the neighbours.

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Problems related to biomass combustion

Biomass is different than coal due to its content, however, the most important factor is the difference in its mineral matter. The use of biomass (in particulair straw) in the process of co-combustion in pulverized coal boilers involves some risks and exploatation hazards.

Combustion of biomass which contains **chlorine** causes chloride corosion hazards.
Even if the fuel does not contain chlorine a large **potassium** content in ash ligninocellulose biomass results in more intensive slugging, which can in turn intensify corosion hazards.

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Examples of some components in ash from biomass and coal

Comp., %	Wood (oak/dąb)	Wheat straw	Ggrass/ hay/siano	Sunflower husks/łuski	Rape straw	Olive pomace	Wood pellets	Hard coal
SiO_2	49,0	41,51	28,28	2,32	22,10	15,10	65,87	42,83
Al_2O_3	9,5	1,00	16,51	0,49	1,73	2,28	3,67	22,11
TiO_2	-	0,00	0,22	0,05	0,15	0,14	0,27	0,98
FeO_3	8,5	0,72	3,43	0,41	0,63	1,30	2,15	20,06
CaO	17,5	8,13	23,59	14,90	20,20	13,40	15,72	5,73
MgO	1,1	1,99	1,81	7,57	1,24	4,26	3,75	1,12
Na_2O	0,5	0,57	0,92	0,10	0,33	4,41	0,65	1,06
K_2O	**9,5**	**31,95**	**22,15**	**36,00**	**23,80**	**26,10**	**7,16**	**1,21**
P_2O_5	1,8	4,42	4,0	4,17	1,43	4,41		0,47
SO_3	2,6	3,28	2,58	-	-	-	0	4,93
Cl^d	**0,02**	**0,21**	**0,19**	**1,28**	**0,50**	**0,37**	**0,02**	**0,2**

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Chloride corrosion hazard

Fuel indicator of chloride corrosion hazard *Paliwowy wskaźnik korozji chlorkowej, PW_k*	Characteristics Charakterystyka	Chloride corrosion hazard Zagrożenie korozją chlorkową
0	Cl < 0,02	Brak
1	S/Cl duże	Bardzo małe
2	S/Cl i K duże	Małe
3	S/Cl małe	Duże
4	S/Cl małe i K duże	Bardzo duże

	Wood/Drewno	Wheat/Pszenica	Rape/Rzepak	Miskantus
A	0,14	1,79	2,47	0,54
Cl	0,01	0,47	0,62	0,11
S	-	0,41	0,31	0,04
K_2O	39,9	32,2	34,4	32,2
PW_k	1 (zagrożenie b. małe)	4 (zagrożenie b.duże)	4 (zagrożenie b.duże)	4 (zagrożenie b.duże)

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Slagging process of heating surfaces in boilers

SUPERHEATER in a steam boiler OP-430
(content of biomass in the flow of fuel 10- 25%)

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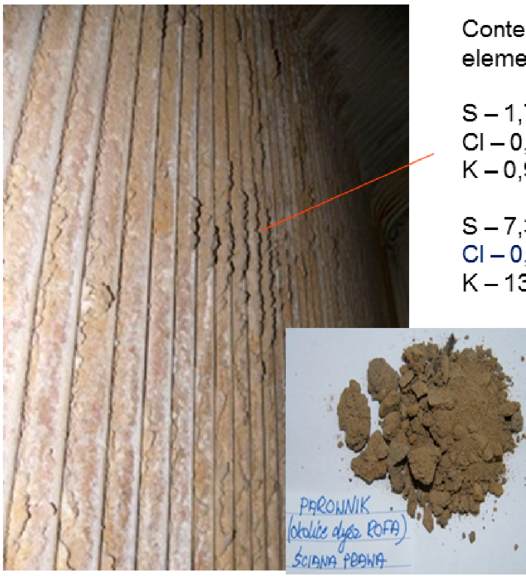
The process of slagging of water walls and superheaters in boilers



Content of chosen elements in deposits:

S – 1,71 %
Cl – 0,03 %
K – 0,92 %

S – 7,39 %
Cl – 0,10 %
K – 13,08 %

RIGHT WATER WALL

SUPERHEATER

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Water wall’s slugging – example 1

Water wall of a pulverized coal boiler kotła pyłowego – approx. 50% of biomass

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Water wall’s slugging – example 2

Melted deposit (slag) flowed on water wall – approx. 50% of biomass

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The effects of corrosion in water wall pipes

Pulverized coal boiler OP-430 (10-25% of biomass)

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Field research of corrosion and slagging processes

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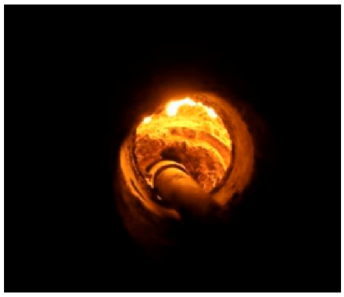
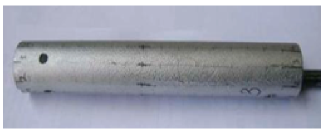
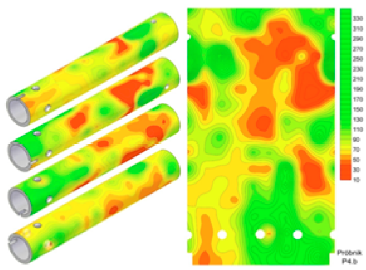
Investigation of corrosion hazards with the use of a probe





CORROSION



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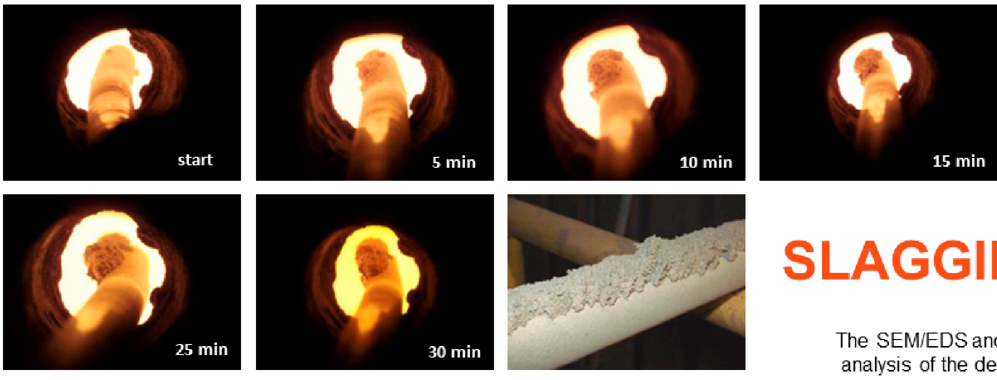
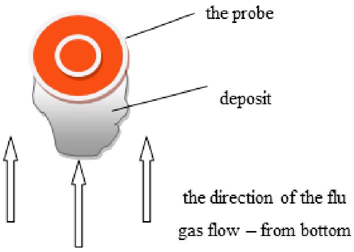
Field research of the deposits with the use of corrosion probe

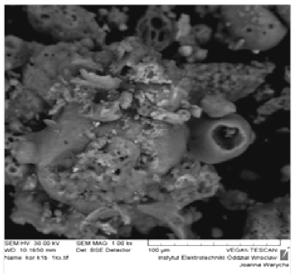


SLAGGING

The SEM/EDS and XRD analysis of the deposits



Video clip



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Laboratory research of corrosion and slagging processes

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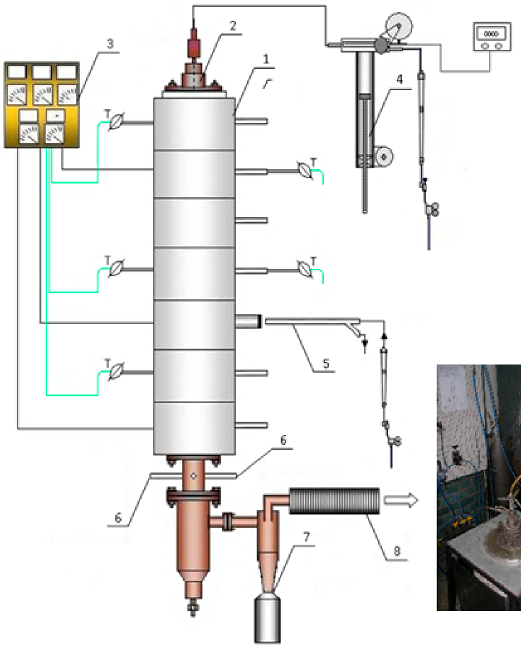
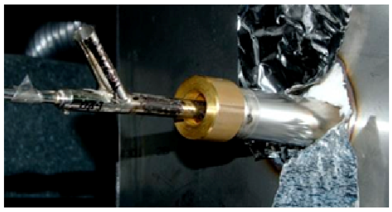
Laboratory apparatus (the drop-tube furnace)





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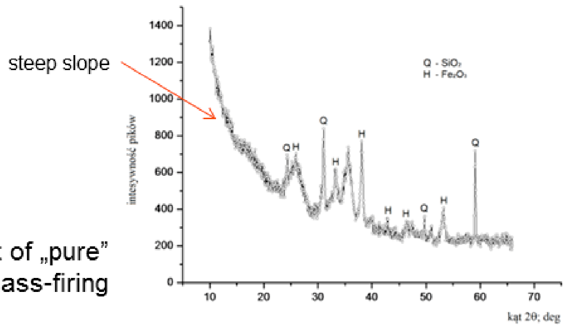
Laboratory investigation of slagging during biomass combustion

The deposite collected on the probe during comustion of agro biomass



Mineral components of deposit of „pure” AGRO biomass-firing

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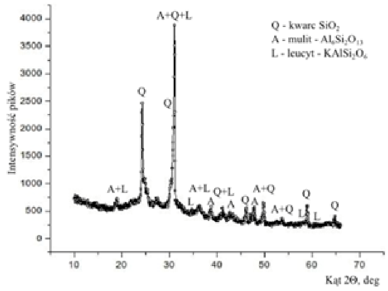
Laboratory investigations of deposits of biomass-firing with additives

The deposit collected on the probe during comustion of the mixture of agro biomass with an additive of selected lignite ash



Mineral components of the deposit in biomass-firing with a mineral additive

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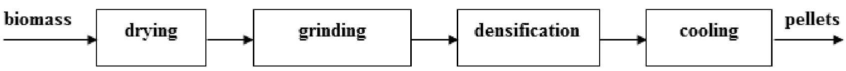
Biomass pelletizing process

Pelletizing - techique of solid biomass densification (eg., sawdust, shavings, flakes, grains, wood chips and straw).

Benefits of biomass pelletizing:
- uniform size,
- high energy density,
- significant calorific value,
- low moisture content,
- easy to grind.



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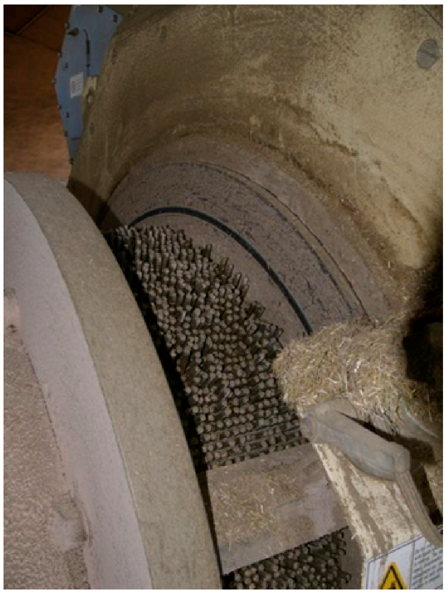
Manufacturing Fuel Pellets from Biomass

Approx. 1t/h



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Manufacturing Fuel Pellets from Biomass

Approx. 5t/h

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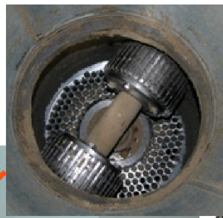
Biomass pelletizing in laboratory scale

Pelletizing device KL200B,
capacity 90 kg/h



Different types of pellets

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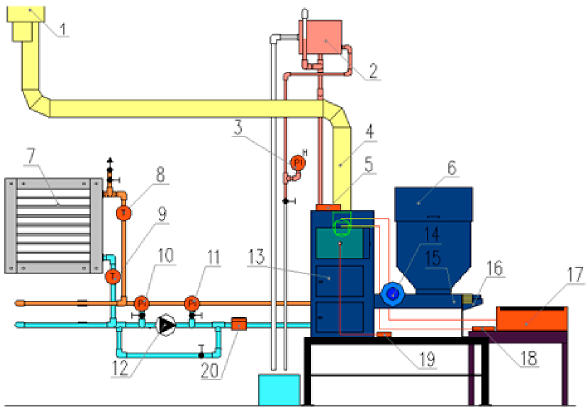
Experimental setup – retort boiler KP15 (15kW)



nominal heating power – 15 kW
maximum water temperature – 90 °C
thermal efficiency – 91 %
flue gas temperature – 190 °C
fuel consumption – 0,65÷3,2 kg/h
boiler water capacity – 48 dm^3
capacity of storage chamber – 100 dm^3

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Pelletizing and combustion of biomass in retort boiler

Investigation of the content of gas pollutants in flue gases (O_2, CO, NO, HCl, VOCs) – the retort boiler 15kW

The effect of different binders on stability of the pellets

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Wood pellets

Video clip

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Influence of a certain type of a fuel on the furnace operation

wheat

miscanthus

coal

The impact of the biomass fuels on the slagging of the retort burner and combustion chamber

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Volatile Organic Compounds and HCl concentration in the exhaust gas

VOCs (LZO) were concentrated on activated carbon, desorbed CS2 and analyzed by gas chromatography.

Formaldehyde was absorbed in water and analyzed colorimetrically.

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	Wood Drewno	Wheat Pszenica	Rape Rzepak	Miscantus Miskantus
Fuel prop. Q_i^a, kJ/kg	16752	14912	14523	15005
A^a, %	0,14	1,79	2,47	0,54
W^a, %	5,04	5,93	5,3	6,44
Cl^a, %	0,01	0,47	0,62	0,12
Thermal power, kW	13,5	13,5	12,2	11,9
Temperature, °C	210-225	220-240	200-225	240-290
Efficiency, %	75,1	71,3	65,9	66,2
O_2, % obj.	10-12	10-12	10-12	12-13
CO, mg/m^3	1230-2000	9250-14800	20300-37000	2200-3700
NO, mg/m^3	134-236	200-270	134-174	187-240
HCl, mg/m^3	22	53	15	5

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Concentration of Volatile Organic Compounds while biomass combustion

VOCs	Wood drewno	Rape rzepak	Wheat pszenica
Aldehydes	945,0	589,3	311,6
Ketones	12,0	27,3	13,7
Alcohols	10,9	1,2	0,6
Esters	n.w.	3,4	n.w.
AH	758,4	598,2	165,9
Other*	189,1	17,9	17,0

AH – aromatic hydrocarbons

Aldehydes: mainly as formaldehyde and acetaldehyde

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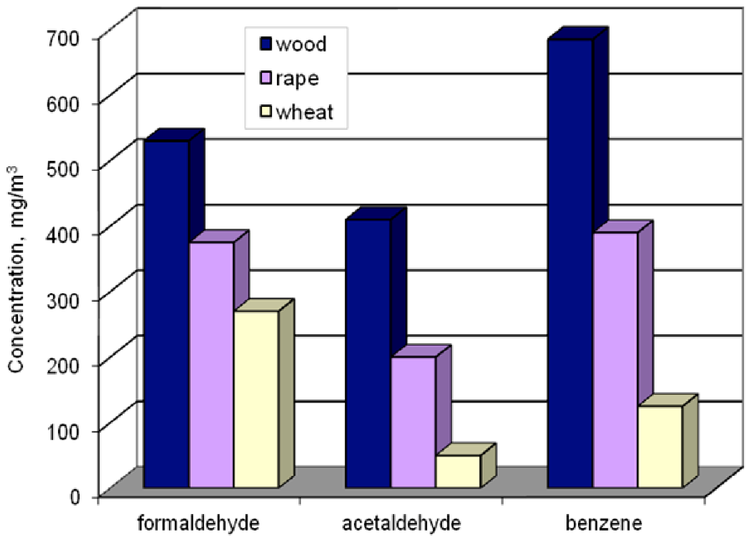
Concentration of Volatile Organic Compounds while biomass combustion



Maximal concentrations of these compounds in the air 50, 20 and 30 μg/m³ respectively)

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Conclusions from laboratory test

Corrosion and slagging as a result of biomass combustion and co-combustion.

The intensity of these processes relies upon the type of biomass.

Chlorine and potassium have the most negative impact on the process of corrosion and slagging during biomass combustion.

Wood pellet combution causes the highest emisson levels of formaldehyde and acetaldehyde and benzene - highly toxic compounds.

Biomass combustion in small boilers results in high emission level of carbon monoxide.

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Safety is an important issue

Explosion risk is connected with each of the following stages of biomass conversion:

1. Unloading
2. Storage
3. Transport of biomass from storage yard to biomass boiler bunkers.
4. Biomass storage in boiler bunkers.
5. Biomass transport from the bunker to the coal mill.
6. Co-milling of coal/biomass in the coal mill.
7. Feeding of pulverised coal/biomass blend to the combustion chamber.

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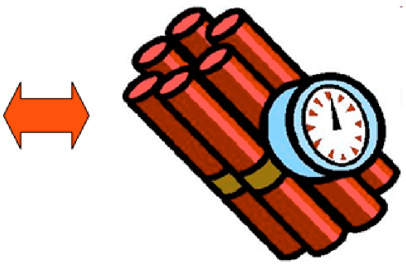
Bad practice during co-combustion of biomass & coal

Biomass deposition on belt conveyor engine



J.Zuwała: TOTeM 37, Sept.2011

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Co-milling of biomass & coal

J.Zuwała: TOTeM 37, Sept.2011

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The risk of fire (explosion) during use of biomass

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Dolna Odra mortal accident - Jan. 24th 2010

Zgliszcza po wybuchu pyłu węglowego w Elektrowni Dolna Odra - 24.01.10.

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Turów Power Plant 2012

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The risks associated with the storage of biomass

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The risk of fire during use of biomass

The risks associated with the storage and transport powdery biomass force to take action to improve safety

- safety /danger zone
- safe device
- determination of explosiveness of biofuels (flammability/explosion limits, temperature of ignition, minimal energy of ignition, etc.)

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The minimum ignition energy of pulverized fuels

Video clip !

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