

LÜHR FILTER

First operating experiences gathered from the conditioned dry gas cleaning system at RDF HKW Stavenhagen

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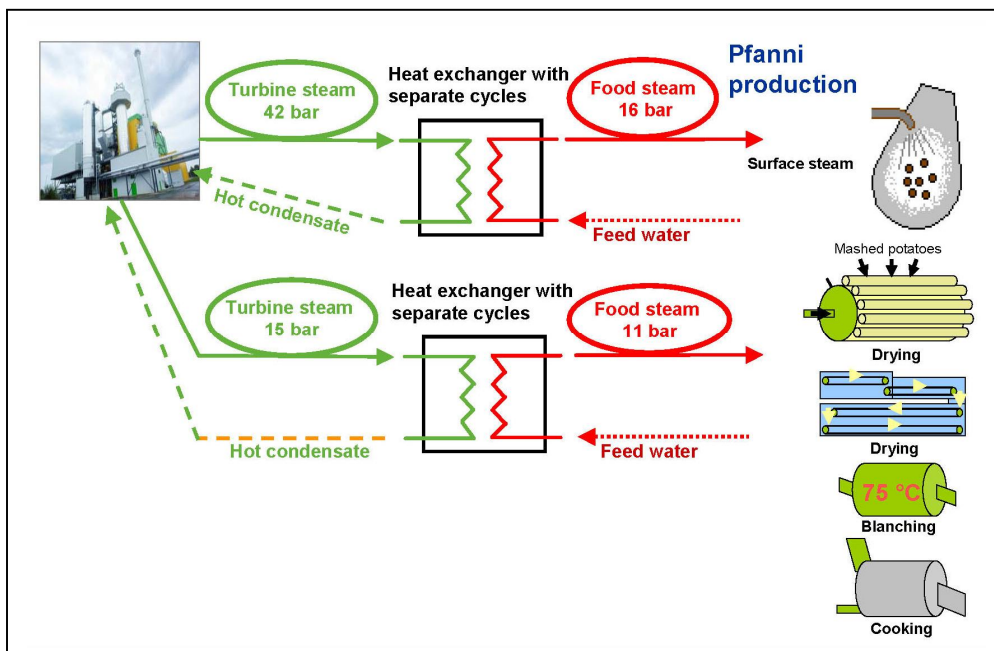
1 Description of entire project

1.1 General design of RDF HKW Stavenhagen

The operator of the RDF HKW Stavenhagen (Refused Derived Fuels combined heat and power plant) (pic. 1) is the Nehlsen Heizkraftwerke GmbH & Co. KG. Since summer 2007, the RDF HKW is supplying the company Pfanni, manufacturer of potato products, with process steam and power (pic. 2) by means of a cogeneration system. Energy supplier and buyer are situated close-by. The electric power not used by Pfanni Stavenhagen and the RDF HKW is fed into an external net.



Pic. 1: RDF HKW Stavenhagen

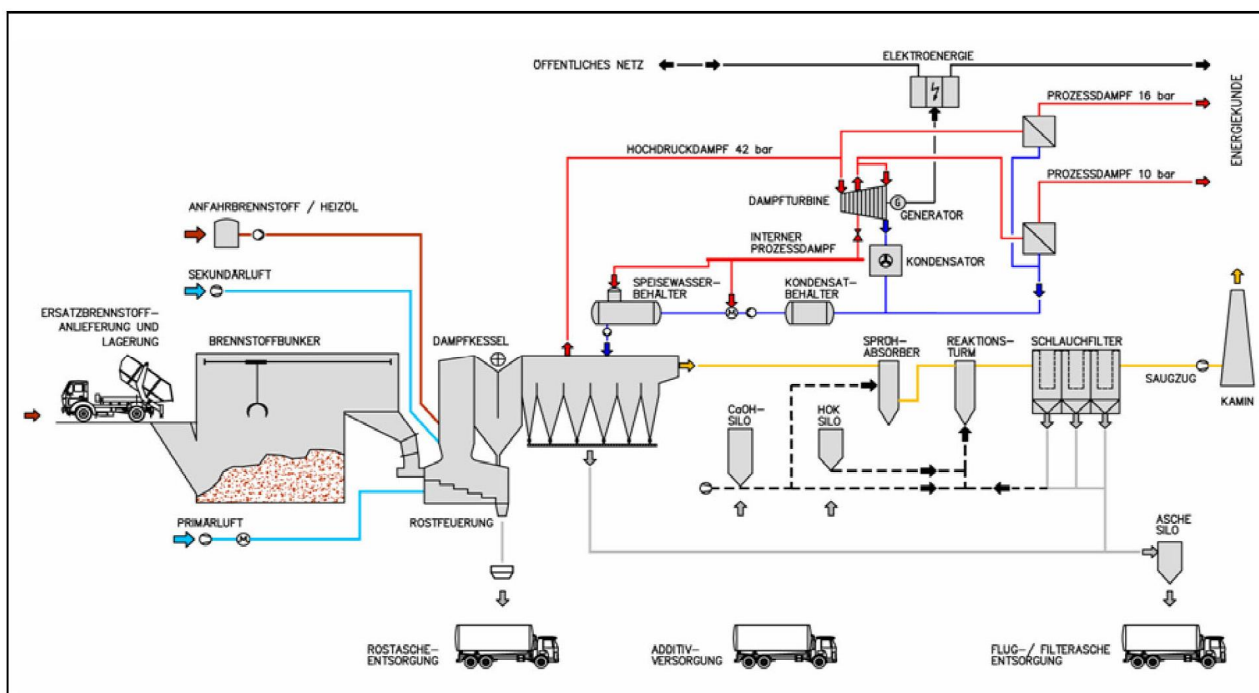


Pic. 2: Interface steam supply, RDF HKW / measuring points potato products

Two companies who are running plants for the production of alternative fuels in Mecklenburg-Western Pomerania, have been engaged as suppliers for fuels. Two-thirds of the fuel consumption are produced close to the heat and power generation plant. Both the short transport route and the possibility of an economical, temporary storage of the fuel during shutdown times of the heat and power plant offer a considerable flexibility regarding the supply. In addition, the largest part of the remainder quantities necessary for the fuel production will be collected from the adjacent rural districts so that the necessary logistics can be realised economically.

The use of locally available fuel generated from waste allowed the realisation of the idea of a recycling management not only with regard to the material recycling but also with regard to the aspect of the energetic utilisation.

The basic design of the RDF HKW is shown in picture 3, the essential technical data are listed in table 1.



Pic. 3: Basic design of RDF HKW

Maximum furnace thermal capacity	49.5	MW
Main steam volume	approx. 53	t/h
Main steam parameter	42	bar (overpressure)
	400	°C
Heating value of alternative fuels	11 up to 18	MJ/kg
Fuel quantity at average net heating value = 14 MJ/kg and/or 3.9 MWh/t	11.5	t/h
Travel time	8,000	h/a
Time availability	90	%

Table 1: Technical data of RDF HKW

1.1 Firing and boiler

The essential part of the RDF HKW is the boiler for RDF with grate bar firing for the generation of high-pressure steam. The alternative fuel will be charged into the feeding hopper for firing by means of a crane. The combustion of alternative fuel takes place on a water-cooled, continuously working moving grate. A water-tube boiler serves as steam generator. The surfaces of economiser and superheater are located in the horizontal part (Tail-End) of boiler.

At the end of the firing grate the incineration residues are thrown into the wet ash extractor and are finally transported to the slag bin. A crane serves for the distribution of residues in the bin and for loading of transport vehicles.

The boiler house is manufactured as a steel construction with a base area of approx. 400m² and a height of 35m. Parts of the boiler (Tail-End) are installed outside. The boiler house does not only comprise firing and boiler, but also different ancillary equipment, especially of the water-steam-cycle.

1.2 Turbogenerator set and air capacitor

The high-pressure steam generated in the boiler is directed to a discharge condensing turbine. The turbine disposes of an extraction socket (16 bar (overpressure) for the provision of the production steam for the Pfanni plant and a bleed connection (3 bar (overpressure) for the provision of auxiliary steam of RDF HKW.

The exhaust steam of low-pressure stage is condensed in an air capacitor plant. The power generation of the turbogenerator set varies depending on the steam extraction by Pfanni. In case of max. extraction, approx. 4.3 MW elt will be generated, in condenser case (no steam extraction by Pfanni), up to 9.6 MW elt.

The condensate from the water-steam-cycle of the heat and power generating plant, mainly consisting of the condensates of the air capacitor and the steam-steam-heat exchangers at the interfaces to the production steam system of Pfanni, is nearly completely re-introduced into the feed water of steam generator. The necessary feeding water for the high-pressure steam cycle will be generated by means of a reverse osmosis device and will be thermically degased.

1.3 Gas cleaning

A high efficiency, two-stage gas cleaning system is installed downstream boiler. The objective of this part of the overall plant is to reduce the concentration of gas components to the limit values of 17 BImSchV., as far as this has not yet been realised as a result of the measures near the combustion and the boiler. The data to be considered for the design of the gas cleaning system are listed in table 2.

	<i>Unit</i>	<i>NOMINAL</i>	<i>MAXIMAL</i>
Volume flow boiler outlet	Nm ³ /h humid	94,800	104,300
Temperature boiler outlet	°C	180	200
N ₂	% Vol. humid	69.0	65.0
O ₂	% Vol. humid	8.6	7.5
CO ₂	% Vol. humid	8.0	7.3
Humidity	% Vol. humid	13.3	20.0
		<i>DAV</i>	<i>DAV</i>
Particles	mg/Nm ³ dry	1,000	1,000
HCL	mg/Nm ³ dry	1,300	2,000
HF	mg/Nm ³ dry	25	50
SO ₂	mg/Nm ³ dry	1,100	1,900
NO _x	mg/Nm ³ dry	200	200
Hg	mg/Nm ³ dry	0.12	0.12
		<i>NOMINAL</i>	<i>MAXIMAL</i>
Σ Heavy metals	mg/Nm ³ dry	27.5 *	100 *
Cd / TI	mg/Nm ³ dry	1.3 *	6.0 *
PCDD / PCDF	ng/Nm ³ dry	3.0 *	4.0 *

*) average value over sample taking period

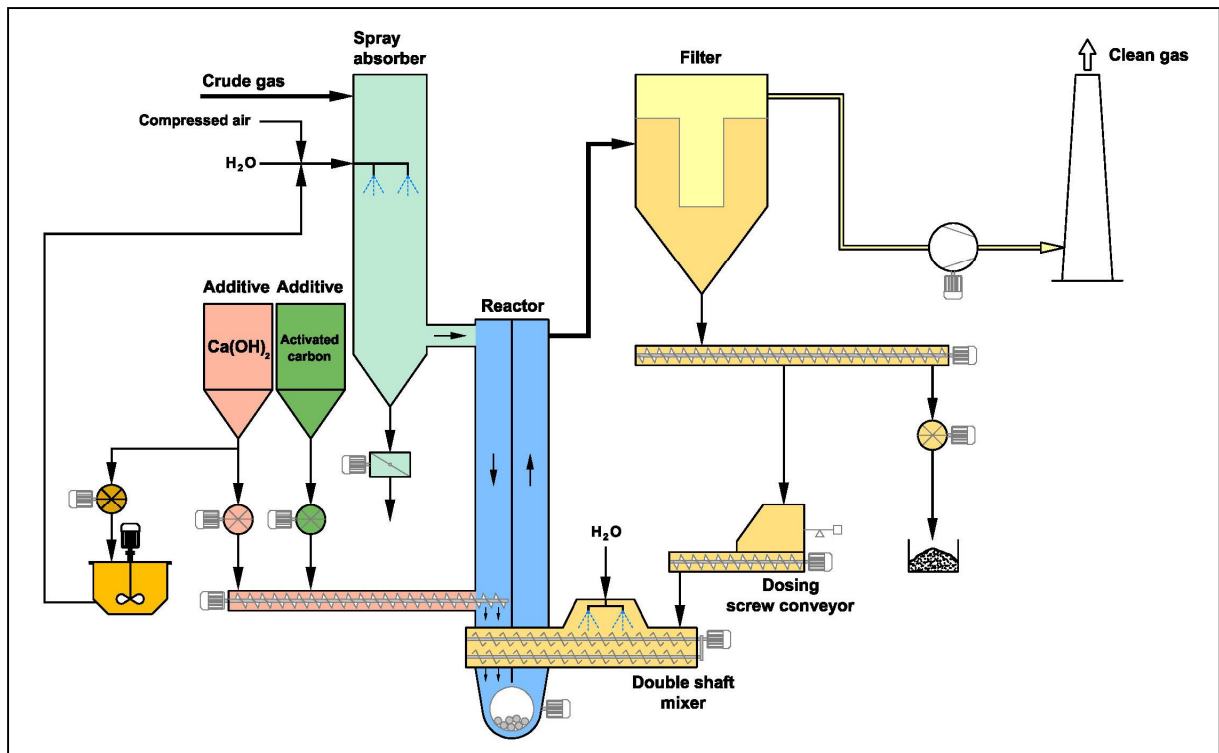
Table 2: Take-over data downstream boiler

The Conditioning Rotor – Recycle Process has been installed for the gas treatment, executed as combination of spray absorption and particle conditioning. A procedure which grants a high separation capacity in connection with low overall costs and the proven, reliable observance of the requested limit values, even in case of crude gas peaks.

2 Combination of spray absorption with particle conditioning (Conditioning Rotor – Recycle Process)

2.1 General structure

A schematic view of this well-proven procedure which has been applied for several years for the reliable observance of the emission limit values according to 17 BlmSchV. is given in pic. 4. It consists of two process stages, installed in series.



Pic. 4: Combination spray sorption – conditioned dry sorption

The first stage of the combined procedure comprises the spray absorber with the following objectives:

- Gas conditioning for the adjustment of an optimum reaction temperature and for the increase in the relative and absolute humidity
- Preliminary sorption by means of lime slurry injection with at the same time reduction of the acid dew point to prevent corrosion.

Due to the fact that especially in case of RDF incinerators and as a result of the fuel composition, the gas humidity is often lower than e.g. in domestic waste incinerators, the possibility of a separate adjustment of an optimum gas temperature gains special importance.

The lime slurry is injected into the spray absorber in finest droplets by means of eight three-component nozzles (lime slurry – water – compressed air), symmetrically arranged over the area. The component parts charged by the lime slurry are

automatically cleaned in regular intervals by means of formic acid. This measure helps to reduce the maintenance works at this plant section to a regular control of nozzles in the spray absorber. Due to the fact that eight nozzles are installed, the plant availability will not be affected.

The second separation stage, mainly used for the crude gas separation, comprises the reactor – filter combination (Conditioning Rotor – Recycle Process) with $\text{Ca}(\text{OH})_2$ injection and multiple particle re-circulation including conditioning of the re-circulated particulate and has the following tasks:

- Creation of good reaction conditions by means of particle re-circulation up to $n \times 100 \text{ g/Nm}^3$.
- Optimisation of SO_2 separation by means of moistening of re-circulated particulate
- Further, even though minor reduction of gas temperature

$\text{Ca}(\text{OH})_2$ and activated coke are fed into the inlet shaft of reaction chamber upstream fabric filter by means of weight-controlled injection. The conditioning rotor in the lower part of the reaction chamber elbow allows the deposit-free feeding and distribution of the additive powders as well as of the re-circulated reaction product even in case of larger load fluctuations.

In addition to the spray absorber, the vertical reactor shaft and the crude gas inlet area towards filter form a further contact and reaction zone in the flow stream for the physical and chemical conversions between the gaseous crude gas components and the additive powder particles at high particle density and offer a residence time for the crude gas in this plant part of approx. 2 sec.

The re-circulation of a defined portion of the reaction product separated within the fabric filter is due to the following reasons: on the one hand, the reaction product still contains reactive and uncharged components and on the other hand, the calcium chloride, presenting a bigger part of the reaction product, is necessary for an effective separation of SO_2 .

The reaction product discharged out of the filter hopper is transported into an intermediate hopper by means of screw conveyors. One screw conveyor, serving as skimming device for the intermediate hopper, transports the excessive material towards the remainder discharge. The portion of particles fed into the intermediate hopper is passed on into double shaft mixers by means of dosing screw conveyors. A part of the process water necessary for the flue gas cooling is injected into the mixers. The wetting of the re-circulated reaction products causes an increase in reactivity of the additive particles due to the influence of water as well as an increase in the water steam content on the surfaces of the additive particles with the positive effect that the sorption efficiency is considerably improved. To grant the highest possible availability even in this section, the humidifying mixers are realised in redundant execution.

The fabric filter has been designed as 6 compartment filter, equipped with vertically installed flat-bags. The cleaning of filter elements takes place by an „on line- pulse jet procedure“. The chosen filter fabric quality is a needle felt quality of 100% PTFE. An additional surface treatment of the filter fabric serves for a good separation efficiency and a low filter differential pressure in continuous operation.

2.2 Distribution of $\text{Ca}(\text{OH})_2$ injection between spray absorber and reaction chamber

The proportioning of the additive powder injection into spray absorber and conditioning rotor reactor is preselected by the operating staff. Normally only a small portion of additive powder (10%) is injected into the spray absorber. Based on the operating experiences gathered from the MHKW Ludwigshafen [1, 2], this adjustment allows an optimum utilisation of the injected additive powder.

Over a period of more than one year, extensive studies concerning the reduction of the additive powder consumption have been realised at the plant of MHKW Ludwigshafen which has a comparable plant structure. Special emphasis was given to the reduction of the CaCO_3 portion in the remainder. With regard to the reaction with HCl and SO_2 , CaCO_3 is only partly available. The lowest calculated stoichiometric factors of these studies have been achieved with disconnected additive powder injection in the spray absorber and complete injection into the reaction chamber. Compared to a 50% : 50% ratio, the calcium carbonate content in the remainder could be reduced from 30 weight% to 20 weight%. The content of free $\text{Ca}(\text{OH})_2$ was increased and the stoichiometric factor was reduced.

The worse operating results in connection with the higher sorption agent injection in the spray absorber are due to the following two reasons:

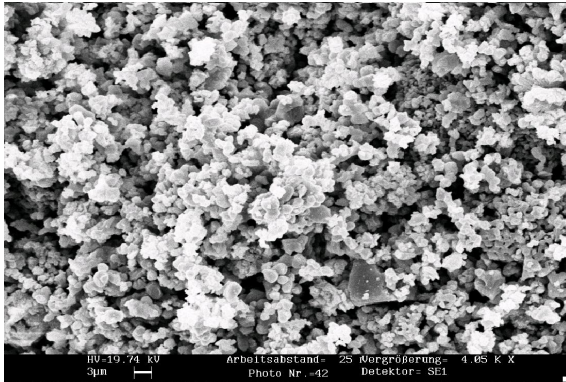
- Formation of CaCO_3 during the aqueous phase

Compared to the acid crude gases HCl , HF and SO_2 , the slightly acid carbon dioxide has a minor affinity to hydrated lime. However, the concentration of CO_2 within the gas is definitely higher. A CO_2 concentration of approx. 10%Vol., corresponding to 100,000 ppm, is faced with a HCl concentration of e.g. 1,600 mg/m³, corresponding to 1,000 ppm. During the wet phase a considerable amount of CaCO_3 will be formed which— after drying of lime slurry drops – will be only very limited available for the reaction.

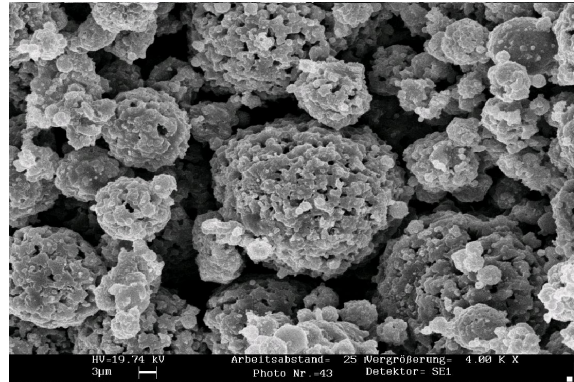
A disadvantage of incinerators for waste and alternative fuels is, that due to the hygroscopic features of CaCl_2 , a temperature reduction to values definitely below 140°C and by this a possible reactivation of the CaCO_3 during the wet phase will not be possible. In case of a corresponding water injection, the downstream installed conditioned dry sorption may lead to a partial reactivation of the CaCO_3 .

- Formation of agglomerates

The microscopic photos in picture 5 show fresh hydrated lime particles compared to calcareous particles extracted downstream spray absorber. The freshly slaked hydrated lime has a clearly visible, high outer surface. However, after drying within spray absorber, this will be reduced due to the formation of drop shaped agglomerates. The exchange surface necessary for the chemical reaction will be reduced.



Fresh hydrated lime



Calcareous particles from a spray sorption
with lime slurry at a waste incinerator

Pic. 5: Surface structure of the hydrated lime, injected as lime slurry [1]

The before-mentioned disadvantages in connection with the additive powder injection into spray absorber lead to the fact that with regard to this technical procedure, LÜHR FILTER lays special emphasis on the crude gas sorption in the second stage – the conditioned dry sorption with multiple particle re-circulation. However, at least a small part of the additive powder should be added in the spray absorber, thus serving as corrosion protection near the water injection into the gas flow for adjustment of the optimum reaction temperature. In addition, the additive powder injection as lime slurry can be helpful with regard to the reduction of crude gas peaks.

As alternative, the spray absorber can be replaced by an evaporative cooler. In this case, the additive will be added as dry powder upstream evaporative cooler and into the reaction chamber by means of graded injection. This process variant will be preferred by LÜHR FILTER for projects in the near future.

The mere spray sorption or also in combination with an additional hydrated lime injection upstream filter does not present an effective alternative procedure. Compared to the process variant spray absorber with particle conditioning or even evaporative cooler with particle conditioning and graded additive powder injection, the achievable additive powder efficiency is lower.

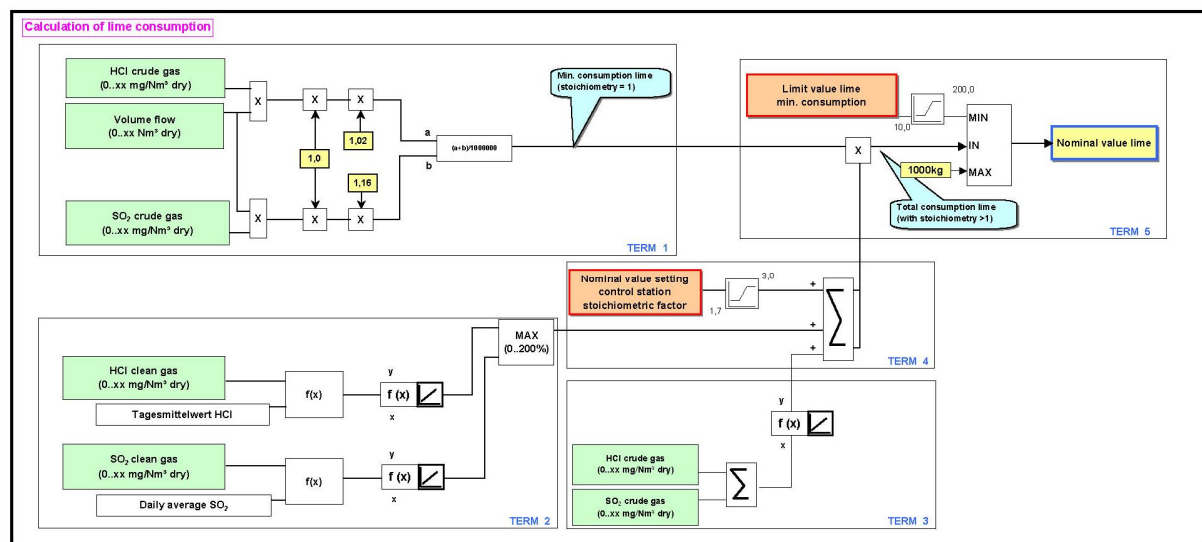
As a general rule, the adjustment of the optimum reaction temperature should not only be effected by means of particle conditioning without evaporative cooler or a spray absorber. Together with a good additive powder efficiency, the material

moistened in the mixer and introduced into the reactor contains reaction products which will – in case of a too high proportional moistening – form very large, non-floating particle agglomerates and/or lead to hard deposits at the reactor walls, which can only be removed by manual intervention. This will limit the max. possible temperature reduction through the particle conditioning in the moistening mixers.

2.3 Control concept for the additive powder injection

2.3.1 $\text{Ca}(\text{OH})_2$

The structure of the control concept applied for the injection of $\text{Ca}(\text{OH})_2$ is shown in the schematic view in picture 6.



Pic. 6: Control scheme Process management and control system

The injection quantity is controlled subject to a given stoichiometric factor. The necessary additive powder mass flow is calculated according to the adjusted stoichiometric factor and on the basis of the volume flow and the HCl and SO_2 values, which are continuously measured in the crude gas upstream spray absorber. In addition to this and in case of increased crude gas values, the stoichiometric factor is automatically increased by means of a superposed adjustment curve.

Furthermore, the monitoring of the emission values, combined with the increase in the injection quantity in case of reaching the clean gas limit values for HCl and SO_2 , ensures that the emission values (DAV and HAV) will by no means be exceeded.

2.3.2 Activated carbon

The activated carbon injection is pre-selected as fixed value in the process management and control system by the operating staff. This value can be increased manually in case of Hg peaks.

In addition it may be remarked that with regard to the separation of mercury and due to the large particle recycle rates near the reactor and filter, the separation capacity of the chosen procedure will be sufficient to control successfully inevitably arising Hg peaks.

3 Operating experiences

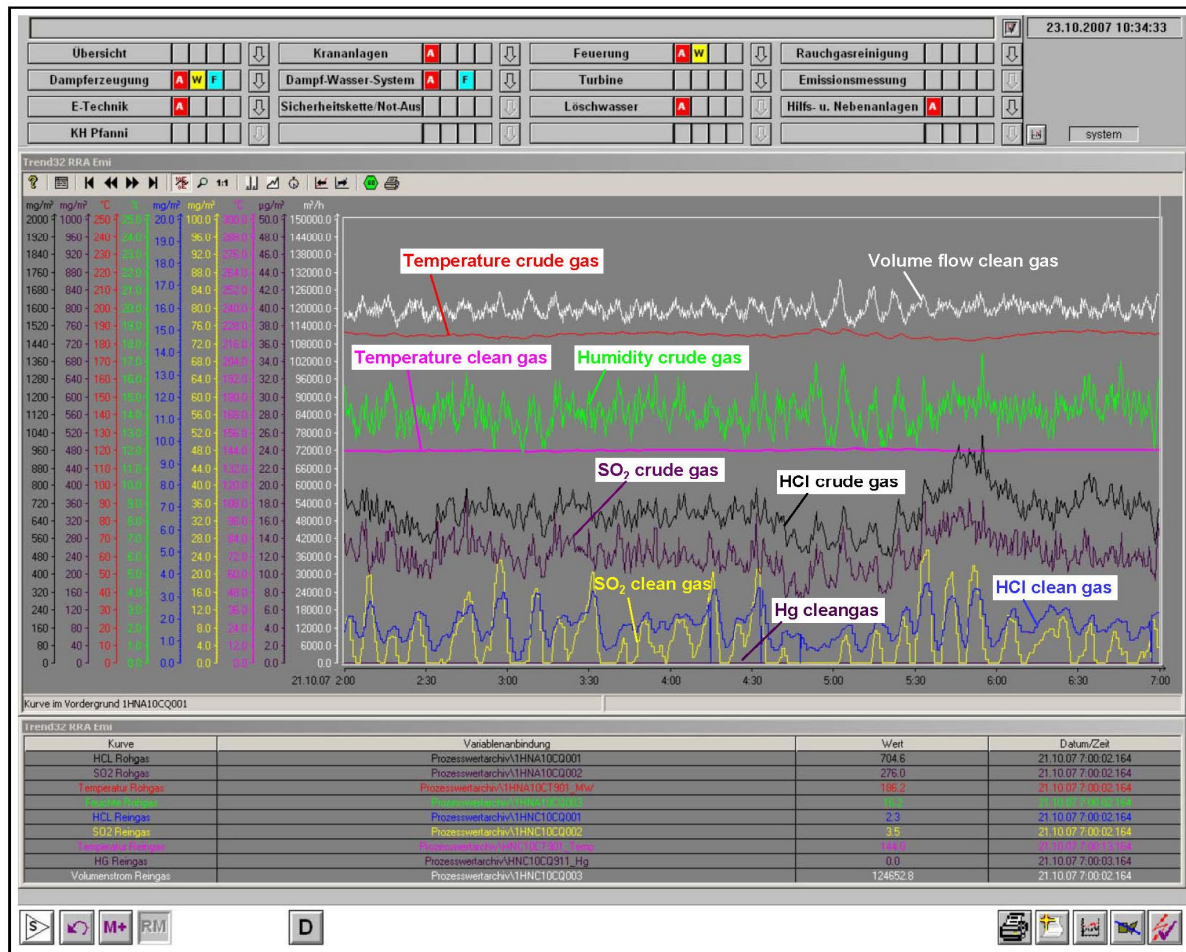
3.1 Additive powder consumption

3.1.1 $\text{Ca}(\text{OH})_2$

After variation of the different setting parameters during commissioning, the plant is now driven as follows:

- The ratio of additive powder injection into spray absorber and conditioning rotor reactor is 10% : 90%.
The $\text{Ca}(\text{OH})_2$ concentration in the lime slurry is limited to max. 12%.
- The temperature upstream filter is adjusted to 140 – 145°C. On the one hand this temperature offers a sufficient distance to the critical temperature, resulting from the hygroscopic features of the reaction products and on the other hand it offers adequate reaction conditions.
- The automatic adjustment of cycle time for the filter cleaning and of the particle recycle rate grants a nearly constant residence time of additive powder particles in the system.
In spite of a low filter differential pressure, the chosen cycle time is comparatively low. In case of a long cleaning cycle and by this long residence times of additive particles in a dry condition with low HCl and SO_2 contents, the $\text{Ca}(\text{OH})_2$ increasingly reacts with CO_2 , i. e. the formation of carbonate increases and the reactivity of additive powder drops.
- The water injection of the two redundant moistening mixers takes place subject to the SO_2 clean gas value.
- The base value for the control of stoichiometry is adjusted to 1.9, whereas in case of increased crude and clean gas values, the stoichiometric factor will be re-adjusted automatically by means of superposed adjustment curves as described in item 2.2.

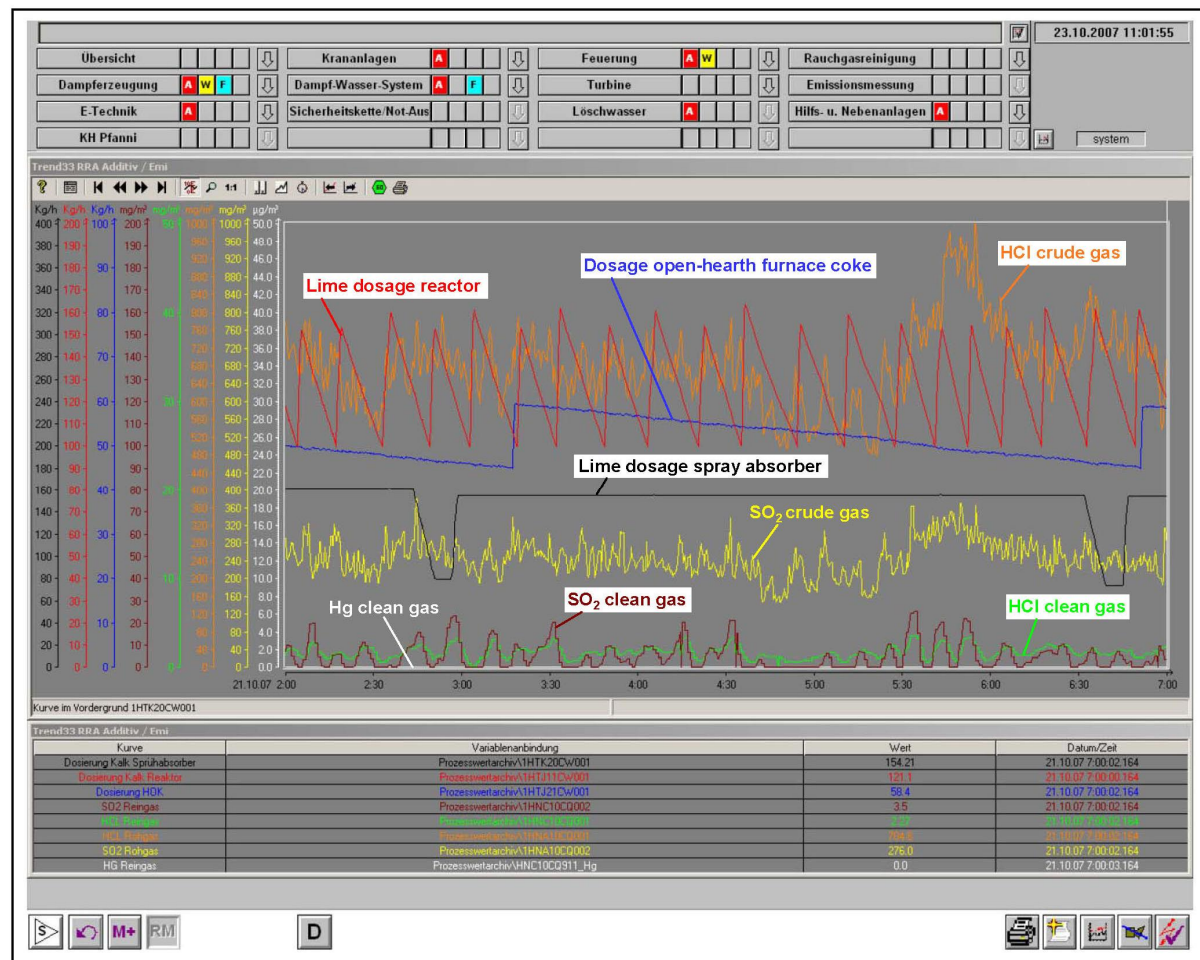
The above-mentioned setting parameters grant the reliable observance of all emission limit values in continuous operation. Picture 7 shows the crude gas and clean gas values for HCl and SO_2 as well as the values for the take-over and filter temperature, the gas humidity and the volume flow over a period of time of five hours by means of trend curves of the process management and control system.



Pic. 7: Trend curves crude/ clean gas values, take-over/ filter temperature, gas humidity and volume flow

Compared to the HCl and SO₂ crude gas values expected during plant design and based on the fuel specification, the values actually achieved since commissioning of plant are definitely lower, especially with regard to SO₂. The average value of 0.6 material% dry substance specified for sulphur anticipates an average SO₂ content in the gas of approx. 1,000 mg/Nm³ dry. The actually found values however, lie in the range of 200 – 500 mg/Nm³ dry. The same applies to the Cl content. The specified average value of 0.8 material% dry substance normally results in a crude gas concentration of 1,100 – 1,300 mg/Nm³ dry. The actually arising concentrations lie between 500 and 800 mg/Nm³ dry.

Similar to picture 7 and for the same time interval, picture 8 shows the trend curves for the additive powder injection quantities. The increase in the Ca(OH)₂ injection quantity near the reactor in case of increasing crude gas values for HCl is clearly visible. The curve progression for the weighing of additive powder dosage is steeper. In spite of the increased crude gas values, the clean gas values nearly remain constant.



Pic. 8: Trend crude/ clean gas values, $\text{Ca}(\text{OH})_2$ injection reactor/ spray absorber, AC injection

As shown in the curve for the dosing into the mixing tank, the preparation of lime slurry takes place in intervals of approx. 3.5 hours.

The comparatively low crude gas concentrations allow to maintain and/or to go below the target stoichiometric factor of 2 even in case of - compared to other plants - low relative humidity and high temperatures in the gas. The average stoichiometric factor actually arising in continuous operation, has repeatedly been calculated by means of remainder analysis. It lies in a range of 1.8 up to 2.0.

Table 3 exemplary shows the analysis of a material sample, taken in October 2007. The stoichiometric factor in this case is < 1.9 . With regard to the product handling, the Cl content of approx. 20 weight% lies in an uncritical range.

On request, the separation capacity of plant can be raised, among other things by an increase in the water injection near the conditioning mixers or by the adjustment of lower temperatures downstream spray absorber.

ANALYSENERGEBNISSE			
Ihre Probenbezeichnung: Filterstaubprobe Stavenhagen Rezi 23.10.07 (Filterstaub in PE-Flasche) Eingangsdatum: 25.10.07 Unsere PEN: A7932-07			
		notifiziert durch die AQS-Stelle Bayern für Nabaltec AG gem. AQS-Nr. 03/11406	
Analyse	Wert	Einheit	Bestimmung mit/gemäß
Gesamt-Ca	29,8	%	DIN EN ISO 11885 E22
CaSO ₃	5,26	%	QSt AA 341 *
CaSO ₄	7,92	%	berechnet
CaCO ₃	8,07	%	DIN EN 1484 H3
CaCl ₂ (wt)	31,4	%	DIN 38405-D1
org. Kohlenstoff	0,81	%	DIN EN 1484 H3
CaF ₂	0,23	%	DIN 38405 D4-1
S ges.	3,27	%	DIN EN ISO 11885 E22
Ca(OH) ₂ ASTM	18,0	%	QSt AA 354 *
Feuchte 105°C	0,81	%	DIN EN ISO 787-2
Hg	10	µg/g	DIN EN 1483 E12 *
Analyse von der gemischten Originalprobe			
* kein akkr. Verfahren			
Nabaltec AG Analysenzentrum			
Ludwig Edenharter (Technischer Leiter)			
Dieses Dokument wurde elektronisch erstellt und trägt daher keine Unterschrift.			

Conversion of analysed substances for determination of achieved stoichiometric factor ¹⁾		
Ca content in substance	Ca(OH) ₂ converted for substance	Residual lime, calculated as Ca(OH) ₂
28,5		
1,8	3,2	
2,3	4,2	
3,2		6,0
11,4	21,1	
0,1	0,2	
9,7		18,0
SUM	28,8	24,0

Ca(OH)₂ input
converted Ca(OH)₂

52,8
28,8

Stoichiometry I		
Ca(OH) ₂ input	=	52,8
converted Ca(OH) ₂	=	28,8
I	=	1,83

1) stoichiometry refers to the separated substances

Table 3: Calculation of stoichiometry from remainder analysis

3.1.2 Activated carbon

Activated carbon with a standard dosing quantity is used as additive powder for the separation of mercury, mercury compounds and dioxins. The continuously measured Hg clean gas values are definitely < 10 µg/Nm³ dry. Measuring results for PCPP/-F have not yet been available at the date of issue of report.

3.2 Spray absorber and lime slurry system

During commissioning, optimisation works have been realised at the lime slurry system. The consumption rate of formic acid has been reduced after a corresponding programme setting concerning the cleaning of lime slurry lines and nozzles.

The maintenance works in this plant section are limited to the regular control of nozzles in the spray absorber. These controls are effected once a week. So far no wear of nozzles has been detected.

Picture 9 shows three out of in total eight spraying lances, distributed over the whole size of spray absorber. The photo was taken on the occasion of a short outage of the overall plant after an operating time of approx. 4 months.



Pic. 9: Spray nozzles inside of spray absorber

3.3 Silo size

One silo with a content of 100 m³ has been installed for the storage of Ca(OH)₂ and one for the remainder with a content of 200 m³. The remainder silo serves for the collection of the fly ash separated in the filter, for the reaction products from the additive powder injection as well as for the collection of the fly ash discharged near the Tail-End of boiler.

Experiences of the first months show that an increase in the storage capacity of both silos would allow a more flexible logistics regarding the supply and return-transport.

3.4 Plant availability

Since commissioning, the gas cleaning system has offered a very high availability. The operation of overall plant has never been affected by this plant section. Besides the already stated optimisation of formic acid consumption and the shortening of chains in the bucket elevator of remainder silo, the adjustment works during commissioning were limited to the usual setting works.

4 Summary and assessment

The first operating experiences gathered from the before-described gas cleaning system confirm its potential and reliability with at the same time high plant availability. All emission limit values can reliably be kept in continuous operation. The achieved stoichiometric factor lies in the range of the pre-selected value of 2. All start-up and shutdown procedures are handled without any problems. On request, the capacity of plant can be increased by an optimisation of the setting parameters for the temperature downstream spray absorber and the water injection near the humidifying mixers.

Finally it may be remarked with regard to the overall project, that the cogeneration of process steam and power in connection with the closeness of a consumer does also offer ecological advantages. The utilisation of fuel through the power plant has a reducing effect on the CO₂. Compared to the separate generation of process steam from natural gas and power according to the German power plant mix as well as to the RDF combustion by means of a waste incineration plant, the resulting economy of CO₂ lies in a range of more than 10,000 t/a. In addition, fossil resources are preserved and transport losses of energy are avoided.

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Dipl.- Ing. Volker Dutge
ete.a Ingenieurgesellschaft mbH, Lich
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VDI Wissensforum Seminar 435918,
Munich, September 14 and 15, 2006

- [2] Dipl.- Ing. Rolf Wradatsch
TWL Technische Werke Ludwigshafen AG
Entwicklung und BetriRDFerfahrungen mit der konditionierten
Trockensorption des MHKW Ludwigshafen
HdT, 3. Fachtagung Trockene Abgasreinigung für Festbrennstoff-
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