

The Use Of Activated Char For Flue Gas Polishing In Municipal And Hazardous Waste Combustors

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INTRODUCTION

During the late 1980's and the early 1990's legislation on emissions from waste combustors were tightened drastically [1, 2]. Also emission limits on „new“ pollutants like dioxins and furans were introduced. Since the flue gas cleaning equipment commonly used before was not designed to meet these emission limits, new technologies had to be developed. Most of these new technologies rely on the use of activated carbon or char for the adsorption of the pollutants [3].

Due to the fact that the amount of activated char used is directly proportional to the mass flow rate of pollutants entering the adsorber, the bulk part of the pollutants has been removed in the preceding gas cleaning stages. Thus the activated char adsorption reactor is employed as a flue gas polishing stage at the end of the APC-train.

In 1984 Steinmüller and its 100 % subsidiary, Hugo Petersen, began to develop flue gas filters for large volume flow rates based on the use of activated carbon. The original goal of development was the removal of residual SO₂ left after the FGD-scrubber, in order to eliminate the problem of ammonia sulfate formation in low-dust SCR-DeNO_x-systems. Shortly after that the catalytic capability of activated carbon to reduce NO_x in the presence of NH₃ was recognized; as well as the suitability of this technology for the flue gas polishing of waste incinerators. In the latter case the removal capability of activated char for a wide range of different pollutants, mainly organics, like PCDD/F's, PCB's, PAH's, etc., highly toxic heavy metals such as Hg, Cd, Pb, etc. and acid gases was of primary interest.

ADSORBER DESIGN

The Steinmüller / Hugo Petersen ACR-technology follows the crossflow principle. Where as the char migrates through the ACR-adsorber vertically from top to bottom, the flue gas flows through the activated char bed horizontally. Figure 1 shows the concept of the adsorber providing a vertical cross section of an activated char bed. Each bed consists of 3 individual layers separated by a perforated shroud. Each layer can be extracted independently, according to its pressure drop, saturation or other guiding parameters. As described in previous papers [4, 5, 6] especially designed cellular discharge cylinders at the bottom of each bed allow the extraction of a precisely defined amount of activated char from each layer individually. Besides a minimization of char consumption, this multilayer design allows for the adaptation of the discharge program to the well known selective adsorption characteristics of the various pollutants [6, 7]. Figure 2 shows how the multilayer design is matched to the characteristic concentrations of adsorbed pollutants within the char bed. The fresh char is conveyed to, and evenly distributed within, the bed by screw conveyors on the top of the bed. The flue gas inlet as well as the outlet of the bed perform important tasks for the correct operation of the filters. The gas outlet insures the retention of even small char particles within the bed. The compounds with a high molecular weight are adsorbed quickly within the first few inches of the activated char, thus pushing the lower molecular weight compounds towards the end of the bed. Due to this reason HCl leaves the bed first, indicating an approaching break-through.

The size of a bed is limited due to specific restrictions, such as the height of the bed, the lengths of the screw conveyors and the discharge cylinders. In order to allow the treatment of large volume flow rates one adsorber unit can be expanded to contain 2, 4, 6 or 8 beds. In this case each bed acts as an individual module within the ACR-unit. Figure 3 shows such an arrangement. ACR's built by Steinmüller / Hugo Petersen treating volume flow rates between 5.000 and 250.000 m³/h and containing up to 8 modules are in operation in power plants as well as in municipal and hazardous waste combustors.

ACR PERFORMANCE

Extensive measurements of the performance of the ACR-technology were obtained at various full scale installations. Among those were municipal as well as hazardous waste combustors in Holland as well as in Germany.

Table I presents a summary of the emission data collected at these facilities. It has to be pointed out that the extremely low emission values reported were measured over a longer period of time, thus accounting for the fluctuations in the inlet pollutant concentration.

The removal efficiency for acid gases, heavy metals and high molecular weight organics was determined to range in the 99.9 % to + 99.99 % region. Especially for acid gases the buffering capacity of the ACR-plant is remarkable. The outlet value of below 1 mg/m³ @ STP for SO₂, for example, remained unaffected even by extremely high peak inlet concentrations of up to 700 mg/m³ @ STP.

Due to the very low outlet concentrations of the various pollutants, significant difficulties were encountered concerning sampling and analysis. Very much care has to be taken regarding the stack sampling and analytical procedures in the lab in order to ensure a reasonable accuracy and precision of the results.

ACR-RETROFITS TO EXISTING MWC'S AND HWC'S

During the early 1980's a significant number of MWC's and few HWC's were built using an APC-train comprised of an ESP, a spray dryer and a baghouse. Representing the state-of-the-art technology 10 to 15 years ago, these APC-trains are unable to meet the stringent emission limits introduced in the early 1990's. Therefore those plants had to be retrofitted. A spray dryer / baghouse combination is capable of removing 90 to 95 % of the pollutants. However, it usually fails to meet the required emission limits by a factor of 1.5 to 2 for the acid gases, and by a factor of 2 to 4 for the heavy metals and the organics. Even though these factors seem high, they represent only a rather small mass flow rate of pollutants. Combined with the fact that the flue gas temperature at the outlet of the spray dryer / baghouse system is commonly adjusted to around 140°C, this makes an excellent basis for a retrofit using the ACR-technology. Figure 4 shows a process flow scheme of such a retrofit at a MWC. The temperature of 140°C is ideally suited for the ACR by being low enough for enhanced adsorption and high enough to avoid any condensation of moisture and/or acids. In most cases a Low Temperature SCR (LTSCR) DeNO_x plant is added at the end of the train. Due to the virtual absence of any pollutants after the ACR, the SCR operational temperature can be reduced to as low as 150 -170°C. This makes the use of SCR a very economical alternative to SNCR, avoiding NH₃-contamination of the fly ash and the spray dryer/baghouse residue. NH₃-contents typically found after SNCR increase the disposal cost of these residues significantly.

Most HWC's built in Europe were equipped with wet scrubbers, even before 1990. The most common APC-train used on HWC's was an ESP followed by a one or two stage HCl-scrubber operated at a pH below 2 and a SO₂-scrubber operated at a pH of around 5 to 6. These systems are better suited to handle the significantly higher pollutant concentrations of HWC's at the inlet of the APC-train. Besides the possibility of retrofitting these facilities with an ACR / LTSCR combination as described above, another option is to add an ACR / ACCR combination as presented in Figure 5. This 125 tpd HWC was retrofitted with an ACR and the ACCR-DeNO_x system [8]. Both the ACR and ACCR are combined in one reactor with the NH₃-injection system upstream of the ACR. In the ACR lignite based hearth oven char (HOC) is used, whereas the ACCR utilizes the catalytic capabilities of hard coal based form activated carbon (FAC). The plant has been in operation since 1991 and NO_x emission values of less than 100 mg/m³ @ STP, 11 % O₂ have been obtained continuously. The advantage of ACCR is its low operating temperature of between 120°C and 140°C. Its disadvantage is that high NO_x-removal efficiencies (> 85 %) cannot be realized due to the catalytic limitations of the activated carbon [8].

ACR FOR NEW MWC'S and HWC'S

In new installations, the ACR forms an integrated part of the APC-train. As presented in Figure 6 such a modern five-stage gas cleaning system is designed to achieve the lowest possible emission limits. Thus a baghouse is employed to insure the best possible removal of particulate matter.

It is followed by a multi-stage wet scrubbing system designed to recover hydrochloric acid from the removed HCl and wall board quality gypsum from neutralized SO₂ [9]. The heat losses through evaporation in the scrubbers are minimized by employing a cross-flow heat exchanger. It cools the flue gas before entering the first scrubber and then reheats the flue gas after leaving the second scrubber. Thus the flue gas is prepared for the final polishing by the ACR before it enters the stack via a LTSCR-DeNO_x plant. To adjust for the appropriate LTSCR-temperature the compression heat liberated in the fan is utilized. The remaining heating is done by a low pressure steam heater. The specific advantages of LTSCR as described elsewhere [10] are ideally enhanced in combination with an ACR.

CONCLUSION

Today, little over 5 years after the introduction of new and stringent emission regulations for MWC's and HWC's, ACR ist a well proven, accepted technology. Table II provides a list of installations of new and retrofitted MWC's and HWC's in Holland, Germany and Austria employing ACR. In these countries the market share of the ACR-technology with respect to other technologies ist about 35 % in the retrofit market and about 65 % in the market for new facilities. The ACR-technology developed by Steinmüller / Hugo Petersen was not only the first of its kind but still leads the way. As can be seen in Table III, Steinmüller / Hugo Petersen holds about 50 % of the ACR-market for power plants and municipal and hazardous waste combustors. The ACR-technology integrated in a modern state-of-the-art multi-stage APC-train represents the leading edge of pollution control for HWC's and MWC's. The fast increasing interest in this technology, especially in environmentally aware countries like Japan, South Korea, Taiwan and the US-leads to the expectation that ACR will soon be considered the best available control technology not only in Europe but all over the world as well.

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Table I Emission Data Obtained at Various Full-Scale MWC's and HWC's

Group	Compound	Data-Points				Unit	
		1	2	3	4		
Acid Gases	SO ₂	0.11	0.20	0.47	0.14	mg/m ³	
	SO _x	0.04	0.07	0.03	0.06	mg/m ³	
	HCl	0.84	0.45	0.63	0.79	mg/m ³	
	HF	0.03	0.02	0.03	0.02	mg/m ³	
	HBr	0.07	0.15	0.13	0.07	mg/m ³	
	HJ	0.10	0.19	0.22	0.10	mg/m ³	
Heavy Metals	Sb	< 3	< 6	< 4	< 4	µg/m ³	
	As	< 5	< 7	< 8	< 7	µg/m ³	
	Cd	< 0.5	< 0.9	< 0.8	< 0.7	µg/m ³	
	Co	< 3	< 4	< 4	< 4	µg/m ³	
	Cr	< 3	< 4	< 4	< 4	µg/m ³	
	Cu	< 4	< 5	< 5	< 15	µg/m ³	
	Pb	< 5	< 8	< 8	< 7	µg/m ³	
	Mu	< 3	< 8	< 5	< 4	µg/m ³	
	Hg	< 0.9	< 1.1	< 0.7	< 0.9	µg/m ³	
	Ni	< 3	< 4	< 4	< 4	µg/m ³	
	Te	< 0.3	< 0.4	< 0.4	< 0.4	µg/m ³	
	Sn	< 3	< 8	< 4	< 8	µg/m ³	
	V	< 3	< 4	< 4	< 4	µg/m ³	
	Other Elements	Al	257	97	278	93	µg/m ³
		Ba	6	11	15	10	µg/m ³
Be		< 0.5	< 0.7	< 0.8	< 0.7	µg/m ³	
B		52	27	46	48	µg/m ³	
Fe		22	41	120	52	µg/m ³	
Mg		16	29	36	29	µg/m ³	
K		52	104	99	60	µg/m ³	
Se		< 5	< 7	< 7	< 8	µg/m ³	
Si		78	45	34	80	µg/m ³	
Ag		< 3	< 4	< 4	< 4	µg/m ³	
Na		279	665	405	321	µg/m ³	
Te		< 9	< 15	< 14	< 13	µg/m ³	
Zn		10	23	19	26	µg/m ³	
Organics		PCDD			0.0238	0.0261	ng/m ³
		PCDF			0.0222	0.0223	ng/m ³
		TEQ (NATO CCMS incl ¼ the detection limits)			0.0009	0.0014	ng/m ³
		PBrDD			< 0.760	< 0.815	ng/m ³
	PBrDF			< 0.760	< 0.815	ng/m ³	
	PAH (E/PA/610)			6.282	4.146	ng/m ³	
	PCB ₆ (Di-Hexa)			3.2	1.8	ng/m ³	
	PCP ₆			12.3	9.2	ng/m ³	
	PCB (Ballschmitter)			10.4	10.4	ng/m ³	
	Benzene			< 95	< 90	µg/m ³	
	Toluene			< 95	< 90	µg/m ³	
	Ethylbenzene			< 95	< 90	µg/m ³	
	p- and m-Xylene			< 95	< 90	µg/m ³	
	O-Xylene			< 95	< 90	µg/m ³	
	Dichloromethane			< 160	< 150	µg/m ³	
	1-1, Dichloroethane			< 265	< 250	µg/m ³	
	Trichloromethane			2	2	µg/m ³	
	1-1-1, Trichloromethane			< 1.1	< 1	µg/m ³	
	Tetrachloromethane			< 1.1	< 1	µg/m ³	
	Trichloroethene			< 1.1	< 1	µg/m ³	
	Tetrachloroethene			< 1.1	< 1	µg/m ³	
	1-1-1-2, Tetrachloroethane			< 1.1	< 1	µg/m ³	
1-1-2-2, Tetrachloroethane			< 11	< 1	µg/m ³		
trans-1-2, Dichloroethene			< 160	< 150	µg/m ³		
cis-1-1, Dichloroethene			< 160	< 250	µg/m ³		
Dichlorobromomethane			< 1.1	< 1	µg/m ³		
Dibromochloromethane			< 1.1	< 1	µg/m ³		

< means that the actual value is below the given number, which represents the detection limit

Table II

List of Installations equipped with activated char adsorbers in Austria, Germany and the Netherlands

Name of Plant	Country	Operator / Consultants	Employed APC-train	Volume Flow Rate	Type of waste	ACR supplier / Licensor	Start-up
AVR RO-0 - RO 6	NL	AVR / Tebodin	ESP-HCl-SO ₂ -ACR-LTSCR	7 x 155.000	MW	AE / STEAG	1993
AVR RO-0	NL		ESP-HCl-SO ₂ -ACR-LTSCR	1 x 155.000	MW	STEAG	1995
AVR DTO-9	NL	AVR / Tebodin	Q-ESP-HCl-SO ₂ -ACR	1 x 77.000	HW	AE / STEAG	1992
AVR DTO-8	NL	AVR / AVR	ESP-HCl-ACR	1 x 77.000	HW	LCS / HP	1994
RZR Herten IM 1	D	STEAG / STEAG	ESP-HCl-SO ₂ -ACR-ACCR	1 x 70.000	HW	LCS / HP	1991
RZR Herten IM 2	D	STEAG / STEAG	ESP-HCl-SO ₂ -ACR-LTSCR	1 x 70.000	HW	LCS / HP	1995
RZR Herten SM 1/2	D	STEAG / STEAG	SD-ESP-HCl-SO ₂ -ACR-LTSCR	2 x 120.000	MW	LUT / WKV	1994
RZR Herten SM 3/4	D	STEAG / STEAG	FF-HCl-SO ₂ -ACR-LTSCR	2 x 157.000	MW	LCS / HP	1999
MVA Düsseldorf-Flingern	D	SWD / SWD	ESP-SD-ESP-ACR-LTSCR	4 x 160.000	MW	LUT / WKV	1993
	D	SWD / SWD	ESP-SD-ESP-ACR-LTSCR	1 x 180.000	MW	LUT / WKV	1997
MHKW Hameln	D	EWAG / VGU	SNCR-DIP-FF-ACR-LTSCR	3 x 60.000	MW	LUT / WKV	1993
EBS Wien	A	EBS / Fichtner	ESP-HCl-SO ₂ -ACR	2 x 68.500	HW	INT / WKV	1992
		EBS / Fichtner	ESP-HCl-SO ₂ -ACR	2 x 126.500	HW	INT / WKV	1992
		EBS / Fichtner	ESP-HCl-SO ₂ -ACR	1 x 74.000	HW	INT / WKV	1992
		EBS / Fichtner	ESP-HCl-SO ₂ -ACR	1 x 15.000	CW	INT / WKV	1990
Hoechst-Frankfurt	D	Hoechst / Hoechst	ESP-HCl-SO ₂ -ACR	1 x 75.000	HW	LUT / WKV	1994
AVG Hamburg	D	AVG / VKR	ESP-HCl-SO ₂ -ACR-LTSCR	2 x 78.000	HW	LUT / WKV	1996
MVA II Stellingermoor	D	Hamburg / GRP	ESP-HCl-SO ₂ -ACR-LTSCR	2 x 131.000	MW	LUT / WWK	1995
AWG Wuppertal	D	AWG / AWG	ESP-HCl-SO ₂ -ACR-LTSCR	3 x 135.000	MW	LTU / WKV	1995
MHKW Essen-Karnap	D	RWE / RWE	ESP-HCl-ACR-LTSCR	4 x 168.000	MW	AE / STEAG	1995
MVA Wets	A	WAV / GRP	ESP-HCl-SO ₂ -ACR-LTSCR	1 x 62.000	MW	AE / STEAG	1995
KVA Uni Heidelberg	D	Hospital / ECH	ESP-HCl-SO ₂ -ACR-LTSCR	2 x 65.000	CW	AE / STEAG	1991
AVI ROTEB	NL	ROTEB / Tebodin	HCl-SO ₂ -ACR-LTSCR	4 x 75.000	MW	LCS / HP	1993
MVA Kassel	D	Stadtreiniger / GRP	ESP-SD-FF-ACR-LTSCR	2 x 70.000	MW	LCS / HP	1996
MVA Stapelfeld 1+2	D	MVA Stapelfeld GmbH / MVS	ESP-HCl-SO ₂ -ACR-LTSCR	2 x 120.000	MW	LCS / HP	1996
MVA Stapelfeld 3+4	D		FF-HCl-SO ₂ -ACR-LTSCR	2 x 157.000	MW	LCS / HP	
MVA Weissenhorn	D	County / AEW	DIP-FF-SO ₂ -ACR-LTSCR	2 x 51.000	MW	LCS / HP	1996
AEZ Kreis Wesel	D	STEAG / STEAG	ESP-SD-ESP-HCl-SO ₂ -SCR-Oc-ACR	2 x 120.000	MW	LCS / HP	1997
RVA Böhlen	D	BAS / STEAG	ESP-SD-FF-HCl-SO ₂ -ACR-LTSCR	1 x 40.000	HW	LCS / HP	1997
MVA Köln	D	AVG / ITG	SD-FF-HCl-SO ₂ -ACR-Oc-SCR	4 x 95.000	MW	LCS / HP	1998
RMHKW Böblingen	D	ABB / GRP	FF-HCl-SO ₂ -ACR-LTSCR	2 x 62.000	MW	LCS / HP	1999
TAD Dortmund		ABB / GRP	ESP-Q-HCl-SO ₂ -ACR-LTSCR	2 x 63.000	MW	LCS / HP	2003

ESP = electrostatic precipitator

SD = spray dryer

SO₂ = SO₂-scrubber

ACR = activated char reactor

SNCR = selective non catalytic reduction

LTSCR = low temperature selective catalytic reduction

MW = municipal waste

SS = sewage sludge

AE / STEAG = Austrian Energy & Environment / STEAG AG

INT / WKV = Integral Engineering / Grochowski

FF = fabric filter

HCl = HCl-scrubber

DIP = direct injection process

ACCR = activated carbon catalytic reduction

SCR = selective catalytic reduction

SCR-Oc = SCR + oxidation catalyst

HW = hazardous waste

CW = clinical waste

LUT / WKV = Lentjes Umwelttechnik / Grochowski

LCS / HP = L. & C. Steinfüller GmbH / Hugo Petersen

Table III**Market Share of Steinmüller / HP of ACR for Power Plants and Waste Combustors in January 1996**

Total Number of Plants (larger than 5.000 m³/h) : 84
delivered by

LCS/HP	50.0 %
LUT/INT	22.6 %
AE/STEAG	21.0 %
Uhde*	3.6%

Total Volume Flow Rate treated : 11.045.000 m³/h net @ STP in ACR's by

LCS/HP	47.2 %
LUT/INT	22.6 %
AE/STEAG	21.0 %
Uhde*	9.2 %

LCS/HP = Steinmüller / Hugo Petersen
LUT/INT = Lentjes Umwelttechnik / Integral Engineering
AE/STEAG = Austrian Energy & Environment / STEAG
Uhde = Uhde Engineering GmbH

- Uhde gave up the ACR product line in 1990 after delivering only 3 ACR units for power plants

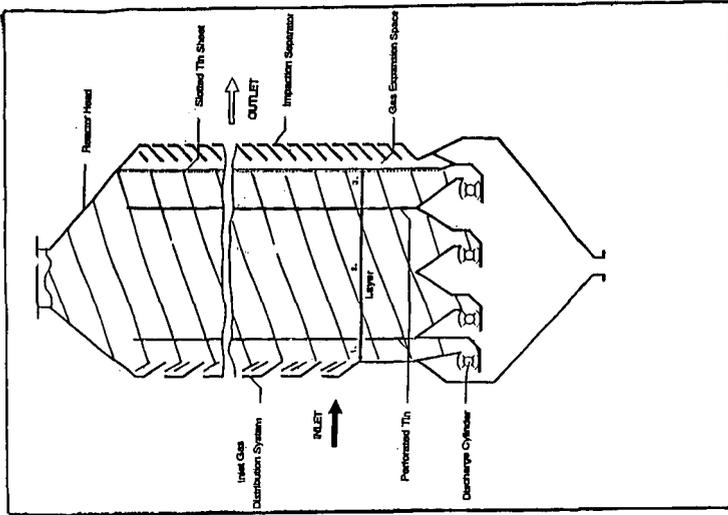


Figure 1 ACR Adsorber Concept

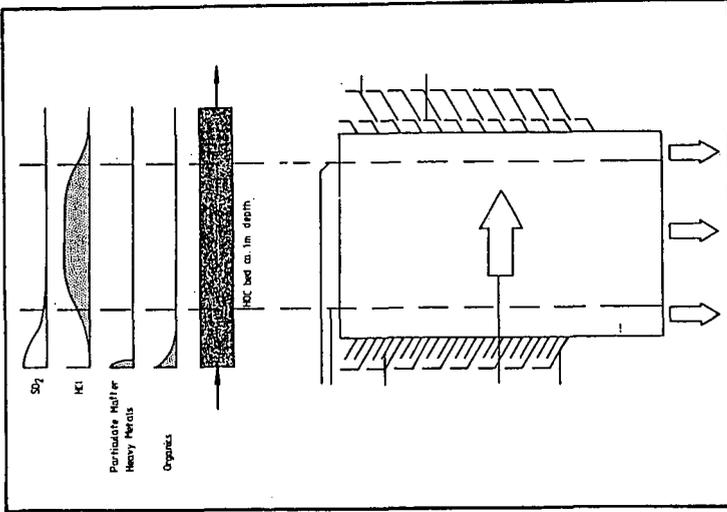


Figure 2 Adsorption Characteristics Adopted by the Adsorber Design

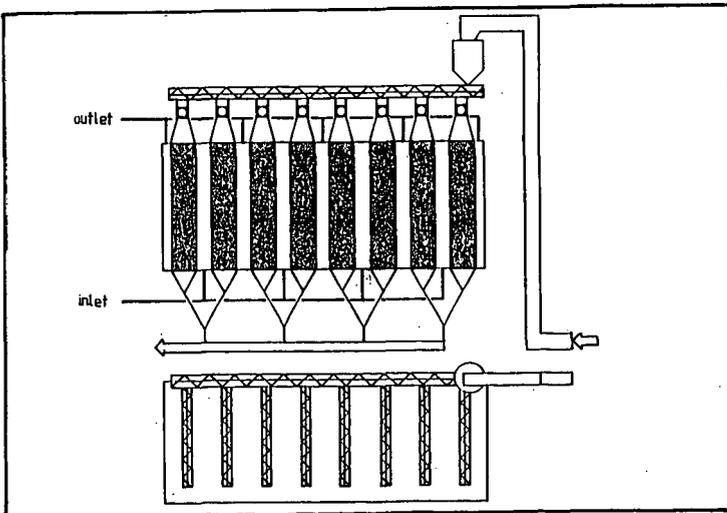


Figure 3 Modular Arrangement Within the ACR Adsorber

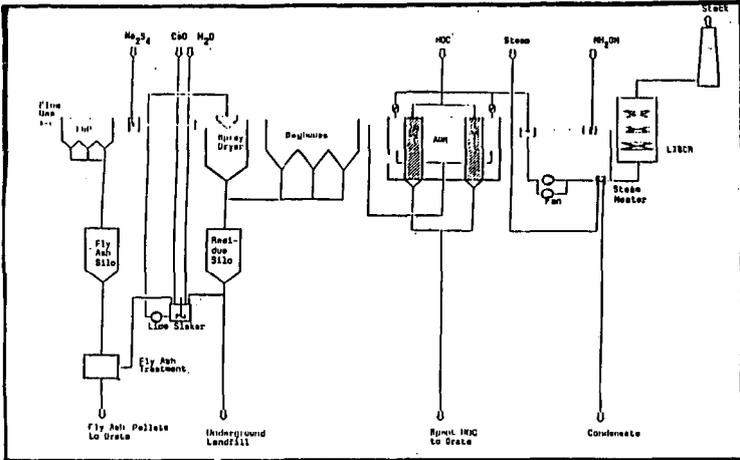


Figure 4 17. BimSchV Retrofit of an Existing MWC

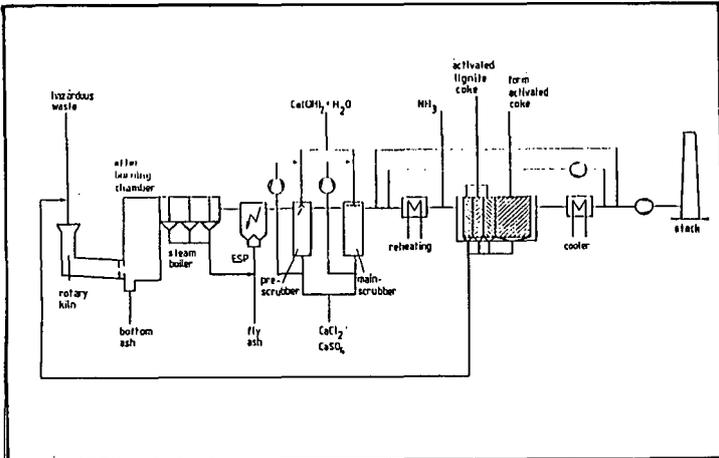


Figure 5 17. BimSchV Retrofit of an Existing HWC

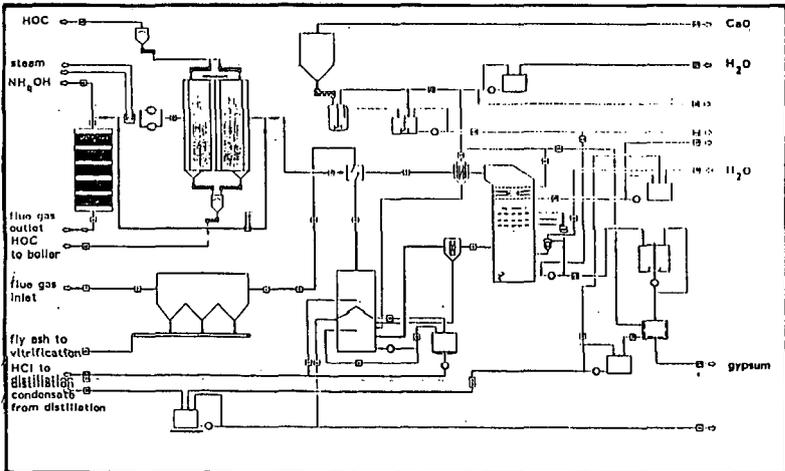


Figure 6 Modern 5-stage APC-Train for MWC's and HWC's