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INDUSTRIAL SYSTEM FOR CONCURRENT REMOVAL OF SULPHUR COMPOUNDS AND PARTICULATES FROM FLUE GASES. A CASE STUDY

The treatment system has been operated by the Match-Making Plant of Bystrzyca Kłodzka (Poland) since 1988. It receives an hourly flue gas volume which approaches $11,000 \text{ m}^3$. The system provides both desulphurization and dedusting of the flue gas stream. The composition of the sorption effluent and waste sludge is shown in tables. Removal efficiencies and method of disposal are discussed.

1. INTRODUCTION

Coal burning as the only source of power generation in Poland gives rise to enormous emissions of sulphur dioxide, which increase with the increasing sulphur content in the fuel. In rough estimates the overall annual losses due to air pollution amounted to approximately US \$ 40,000,000 in 1989. Presently over 35% of Poland's population live in highly polluted regions with airborne concentrations several times as high as the admissible values. The majority of Poland's inhabitants are exposed to pollution episodes with concentrations above any air quality standard [1]. There is also transboundary transport on air pollutants from Poland to other countries which insist on our abating the pollution volume produced. Unfortunately, after decades of neglect, the state-of-the-art in pollution control has become deplorable. Implementation of desulphurization technologies on an industrial scale is still far from being satisfactory.

In the past few years, only a few industrial systems for concurrent removal of sulphur compounds and particulates from flue gases have been implemented in Poland. All of them involve a wet process referred to as the modified double-alkali method which has been developed by the research staff of the Air Pollution Control Laboratory, Institute of

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Environmental Protection Engineering, Technical University of Wrocław. The systems work for the needs of small boiler rooms.

The system selected for the purpose of this study has been operated continuously by the Match-Making Plant of Bystrzyca Kłodzka, Lower Silesia, Poland, since 1988. The investigations covered the time span from mid-August to the end of October, 1990, and were concentrated on two major problems - waste sludge management and the method by which the effluent from the absorption process was sprayed in the scrubber. Some of the results are discussed in detail.

2. EXPERIMENTAL

2.1. AIM OF THE STUDY

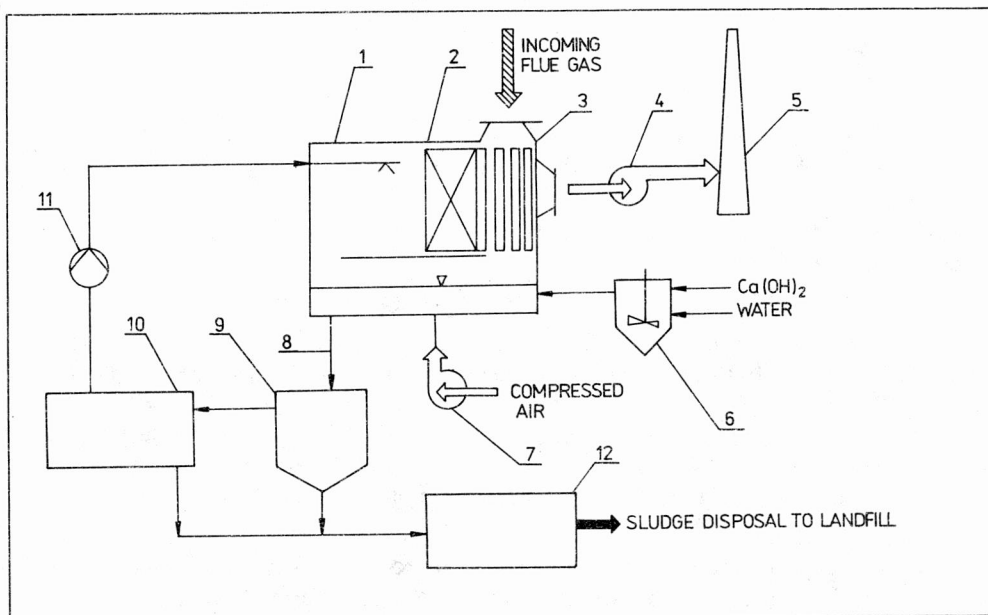
The objective of the study was to determine the following items: actual efficiency of desulphurization, actual efficiency of particulate removal, composition of the sorption effluent, composition of the waste sludges and optimum lime doses at determined operating parameters of the system.

Investigations were begun in August 1990, following a modification of the treatment system. Before that date, the apparatus had mainly received the flue gas stream from a Babcock-type boiler fired with wood wastes. Needless to say that the results obtained (the composition of waste sludge and sorption effluent) failed to be adequate, since the majority of boiler rooms in Poland are coal-fired. The modification of the apparatus consisted in the substitution of compressed-air/water nozzles for the water-nozzles being in use so far.

2.2. FLUE GAS DESULPHURIZATION (FGD) APPARATUS

The flow diagram for the FGD system is shown in fig. 1. The flue gas stream from the boiler (OR-5 or OKR-5 operated alternately) is sent to the absorber (1). Precooling of the gases takes place upon passing through the heat exchanger (3). The flue gas stream then gets in touch with the sorbing solution atomized by an air-water nozzle. Passage through the horizontal section of the scrubber (1) accounts for further cooling, for the separation of particulates and for partial desulphurization. Sulphur dioxide and the remaining particulates are removed during flue gas flow through the vertical section of the scrubber. After passage through the demister (2) and after heating in the heat exchanger (3) the purified stream is sent to the stack (5) via a fan (4).

The sorbing solution (which circulates in a closed-loop system) is a saturated solution containing calcium salts and alkalies washed away from the particulates carried by the flue gas stream. The effluent from the sorption process is received by the tank in the bottom part of the scrubber. The tank is fed with whitewash (6) and compressed air (7) for the regeneration of the sorbing solution and for the oxidation of the salts produced in the course of absorption, respectively. The whitewash dose depends on the SO_2 content in the flue gas stream, and is controlled according to the pH value of the suspended solids leaving the scrubber. Following regeneration, the suspended matter produced in the sorption pro-



Flow diagram of the FGD system

cess is passed (by overfall (8)) from the absorber (1) to the vertical settling tank (9), and from there to the labyrinth settling tank (10) for further separation of phases. The effluent from the labyrinth settling tank is clear, so it is sent to the absorber nozzles through a pump (11). The sludges deposited during sedimentation are dewatered via natural evaporation in the thickener (12). After thickening, the sludges are disposed of on municipal landfills.

2.3. METHOD

The efficiency of FGD was determined by iodometry (SO_2 concentrations in the flue gas stream were measured before and after passage through the apparatus) and was calculated using the following formula:

$$\eta_{\text{SO}_2} = \frac{c_1 - c_2}{c_1} \cdot 100 \%,$$

where c_1 is SO_2 concentration before passage through the treatment system (mg/m^3), and c_2 is SO_2 concentration after passage through the treatment system (mg/m^3).

Because of the high moisture content in the flue gas stream, particulate concentrations were measured by absorption in scrubbers with distilled water as absorbent. The suspended matter obtained was dewatered by evaporation and the dry residue was weighed. The efficiency of separation was calculated as follows:

$$\eta_p = \frac{c_{1p} - c_{2p}}{c_{1p}} \cdot 100 \%$$

where c_{1p} is particulate concentration before passage through the treatment system (mg/m^3), and c_{2p} is particulate concentration after passage through the treatment system (mg/m^3).

The chemical composition of the sorption effluent was established by determining the content of the following ions:

SO_4^{2-} , SO_3^{2-} , Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Mn^{2+} , HCO_3^- , Cl^- , NO_2^- and NO_3^- (total).

The composition of the waste sludge was determined by thermal analysis and standard methods of chemical analysis (mineralization and, thereafter, determination of individual ions).

3. RESULTS AND DISCUSSION

The experiments were run for nine weeks. The results are listed in tables 1–3. These are the average values taken from the most characteristic experimental series.

3.1. EFFICIENCY OF FGD AND PARTICULATE REMOVAL

The rate of flue gas flow through the treatment system averaged from 10,000 to 13,000 m^3/h . Influent concentrations of SO_2 and particulates varied from 230 to 600 mg and from 470 to 1900 mg per cubic meter, respectively. This variability should be attributed to the varying quality of the coal burnt. Under these conditions, the efficiency of FGD and the efficiency of particulate separation ranged from 90 to 95% and from 96 to 98%, respectively. Effluent concentration of SO_2 approached 65.0 mg/m^3 , whereas the maximum concentration of particulates in the gas stream leaving the stack amounted to 50 mg/m^3 . Flue gas temperature at the outlet of the apparatus varied between 70 and 80°C. Pressure drop ranged from 750 to 900 Pa, according to the flue gas volume.

3.2. COMPOSITION OF THE SORPTION EFFLUENT AND WASTE SLUDGE

The FGD process is run so as to provide a pH greater than 7.0 for each medium circulating in the treatment system (the optimum pH ranging between 7.0 and 9.0). To keep the pH value in the range desired, it is necessary to ensure appropriate dosage of whitewash, i.e. to provide a smooth run of the automated whitewash dosing system. The lime feeder is controlled automatically according to the pH of the sorption effluent leaving the scrubber. It is obvious that reliable functioning of the pH-meter and lime feeder implies optimum operating parameters and minimum lime consumption throughout the process. In the course of the FGD process, malindications of the pH-meter were observed several times. As a result, the lime doses applied were far too high, thus contributing to an increased pH of the sorption effluent, and to an increased CaCO_3 content in the sludge. After several days of operation, the solution reached the state of saturation, and there

Efficiency of FGD and particulate separation

No. and date of measurements	SO ₂ concentration		Particulate concentration		Efficiency		Rate of flue gas flow (m ³ /h)	Flue gas temperature		Pressure drop (Pa)	
	Influent	Effluent	Influent	Effluent	Desulphu- rization	Particulate separation		Influent	Effluent		
	(mg/m ³)		(mg/m ³)		(%)			(K)	(K)		
I	20-26 VIII	229	24	470	43	90	91	10,283	483	343	750
II	27 VIII-2 IX	349	17	897	41	95	95	11,107	523	347	820
III	10-16 IX	609	61	1281	50	90	96	12,710	533	351	910
IV	17-23 IX	374	17	1186	49	95	96	11,321	530	348	830
V	1-7 X	361	17	1016	46	95	95.5	10,907	528	345	780

Table 2

Composition of the sorption effluent from the FGD system (averages)

No. of measure- ment	pH of sorption effluent	Concentration								
		SO ₄ ²⁻	Cl ⁻	NO ₃ ⁻ + NO ₂ ⁻	HCO ₃ ⁻	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Mn ²⁺
		(mg/m ³)								
I	7.2	1652	783.0	0.31	220.0	1093.0	8.3	49.0	91.0	0.10
II	10.0	1696	820.0	0.28	39.9	1210.0	8.6	51.0	97.0	0.08
III	7.8	1650	805.0	0.25	136.8	1080.0	8.5	58.0	110.0	0.10
IV	9.1	1690	1100.8	0.08	43.1	1130.0	8.1	59.0	92.0	0.05
V	8.5	1691	1235.0	0.5	42.7	1200.0	8.5	60.0	90.0	0.06

Table 3

Composition of waste sludge from the FGD system (averages)

No. of measurements	CaSO ₄ · 2H ₂ O	CaCO ₃	Particulate and other compounds	Ca	Fe	Mg	K	Na	Zn	Mn	Pb	Ca(OH) ₂ consumption
	(%)											
I	48	10	42	16.2	1.84	1.47	0.27	0.29	0.27	0.05	0.02	60
II	45	15	40	17.0	1.77	1.32	0.31	0.30	0.25	0.04	0.02	108
III	50	12	38	16.8	1.80	1.46	0.30	0.28	0.27	0.05	0.02	195
IV	44	16	40	17.2	1.83	1.46	0.29	0.27	0.26	0.05	0.03	115
V	47	14	39	16.9	1.80	1.47	0.26	0.29	0.27	0.04	0.02	105

were only slight variations in the concentrations of individual ions. The composition of the sorption effluent is shown in table 2.

Table 3 presents the composition of the waste sludge from sorption. Thus, in the dried sample, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ and CaCO_3 accounted for 45–50% and 10–15%, respectively, whereas the remainder (about 40%) consisted of dust particles absorbed from the flue gas stream, $\text{Ca}(\text{OH})_2$, precipitated metal hydroxides and other sulphates. Calcium carbonate is produced in the reaction of excess $\text{Ca}(\text{OH})_2$ with CO_3^{2-} ions originating as a result of CO_2 sorption from the flue gases. Calcium carbonate content in the sludge is pH-dependent. When pH in the sorption effluent (viz. excess lime) increases, so does calcium carbonate sludge. Metal content in the sludge depends primarily on the composition of the particulates washed away from the flue gas stream. Thus, in the sludge investigated, iron and magnesium accounted for about 1.5 to 1.8% (dry wt.). Sodium, potassium, manganese, zinc and other metals occurred in small amounts (below 1% dry wt.).

Analysis of waste sludge samples after desulphurization revealed no sulphites. This indicates that there was complete oxidation which eliminates the potentiality for leaching of acid compounds during storage on landfills.

The investigations have led to the following finding: optimization of the lime dosing process abates the calcium carbonate content in the waste sludge and minimizes calcium hydroxide consumption in the regeneration of the sorption effluent.

Another major problem is the disposal or management of the waste sludge [2]. The sludge has a moisture content of 60 to 70% by volume and can be disposed of in a waste remover or a water wagon.

4. SUMMARY

The treatment system has been operated by the Match-Making Plant for nearly two years now. The efficiencies of FGD and particulate separation are consistent with the world standards. The reliability of operation was found to depend on the following:

- 1) appropriate functioning of the lime dosing unit and accurate measurement of pH in the sorption effluent,
- 2) degree of clarification of the sorption effluent in the settling tanks, which provides a smooth run of the pumps and nozzles,
- 3) maintenance of pH within the range of 7.0–9.0 throughout the process,
- 4) degree of demisting of the flue gases leaving the treatment system and their heating to a temperature higher than 72°C ,
- 5) competence and skill of the manpower involved (no high-specialized attendance is needed).

Substitution of compressed-air/water nozzles for the existing water-nozzles not only has raised noticeably the efficiency of the FGD process and particulate separation, but has also improved the functioning of the nozzles themselves. A major drawback is the increase in power demand by approximately 30%.

Waste sludge, a by-product of the FGD process, is completely oxidized, displays an

alkaline pH and raises no disposal problems. According to its composition, the sludge is classified as a waste material of a low noxiousness to the environment [2].

The treatment system is of use when applied to coal- or oil-fired small and medium-sized boiler rooms. Capital costs and operating costs approach US \$ 3,200 per 1000 m³ of flue gas and US \$ 200 per 1000 kg of SO₂ removed, respectively.

REFERENCES

- [1] *Method of Abating SO₂ Emissions into the Atmosphere. Proceedings* (in Polish), Eco-Engineering Services "Eko-Geo", Ltd., Gdańsk 1989.
- [2] GROCHULSKA-SEGAL E., *Estimating the Environmental Impact of Sludges from FGD in a Match-Making Plant. A Case Study* (in Polish), PURE AIR, Ltd., Wrocław 1990.

PRZEMYSŁOWE ODSIARCZANIE I ODPYLANIE GAZÓW SPALINOWYCH

Представлено wyniki badań eksploatacyjnych instalacji odsiarczania spalin z kotłowni w Zakładach Przemysłu Zapalczanego w Bystrzycy Kłodzkiej. Została ona uruchomiona w 1988 roku i jest pierwszą pełnopromysłową instalacją eksploatowaną bez przerwy do dziś. Oczyszcza gazy odlotowe w ilości ok. 11 000 m³/h. Przedstawiono wyniki badań średnich skuteczności odsiarczania i odpylania spalin, omówiono skład roztworów i osadów posorpcyjnych pod kątem ich uciążliwości dla środowiska.

ПРОМЫШЛЕННАЯ СИСТЕМА ОДНОВРЕМЕННОГО УДАЛЕНИЯ СОЕДИНЕНИЙ СЕРЫ И ТВЕРДЫХ ЧАСТИЦ ИЗ ДЫМОВЫХ ГАЗОВ

Представлены результаты эксплуатационных исследований аппарата для обессерения дымовых газов из котельной на Спичечном заводе в Быстржыцы Клодзкей. Он был пущен в 1988 году и является первой полнопромышленной установкой, эксплуатируемой без перерыва до сих пор. Он очищает ок. 11000 м³ отходящих газов в час. Представлены результаты исследований средних эффективностей обессерения и обеспыливания дымовых газов, обсужден состав растворов и послесорбционных осадков с точки зрения их обременительности для среды.