‘Lucerne 2000’ waste-to-energy plant with new clean-air system

As a result of new clean-air legislation in Switzerland, the operators of the waste-to-energy power plant at Lucerne invited tenders for equipment that would enable it to comply with more rigorous emissions limits. The plant, which has three combustion lines, was at the time equipped with electrostatic precipitators and single-stage wet scrubbers, and it was envisaged that the new equipment would comprise wet scrubbers, wet electrostatic precipitators and selective catalyst denox stages. ABB Fläkt Industri submitted a tender proposing a filsorption unit in place of the wet ESP. A subsequent evaluation showed that this unit has several advantages, and the company was duly awarded the contract in May 1993. After successful commissioning and performance testing, the new Air Pollution Control plant went into service in August 1996, since when it has been operated continuously. The new equipment has proved to be a cost-effective solution to air pollution control problems at waste-to-energy plants.

Lucerne’s waste-to-energy plant **1** was built in 1971 with two combustion lines, each with a capacity of 3–4 t/h. In the 1980s, a third line was built and the two original lines were modernized with, among other things, larger electrostatic precipitators and a single-stage wet scrubber. After being cleaned, the water from the plant’s scrubbers is discharged into a nearby river.

Boilers operating at a pressure of 35 bar and a temperature of 370 °C supply steam to a 5-MW turbine-generator, which feeds electricity into the local grid. In addition, hot water is produced for a hospital situated a few kilometers from the power plant.

The plant is operated continuously, with short stops for boiler cleaning and longer stops for the annual overhaul. Municipal solid waste as well as some industrial waste with a calorific value of 10–12 MJ/kg is used as fuel. The total yearly capacity of the plant is 84,000 t of waste.

1991 saw new clean-air legislation (LRV91) come into force, as a result of which it became necessary to install a new air pollution control system that would enable the stricter requirements to be met.

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Evaluation and new air pollution control system

The published specification stipulated:

- Gas/gas heat-exchangers around the wet scrubber
- Two-stage wet scrubbers
- Wet electrostatic precipitators
- ID fans
- Gas/gas heat-exchangers around the SCR-denox unit
- Final heating with natural gas as fuel
- Selective catalytic NO_x reduction (SCR) with ammonia

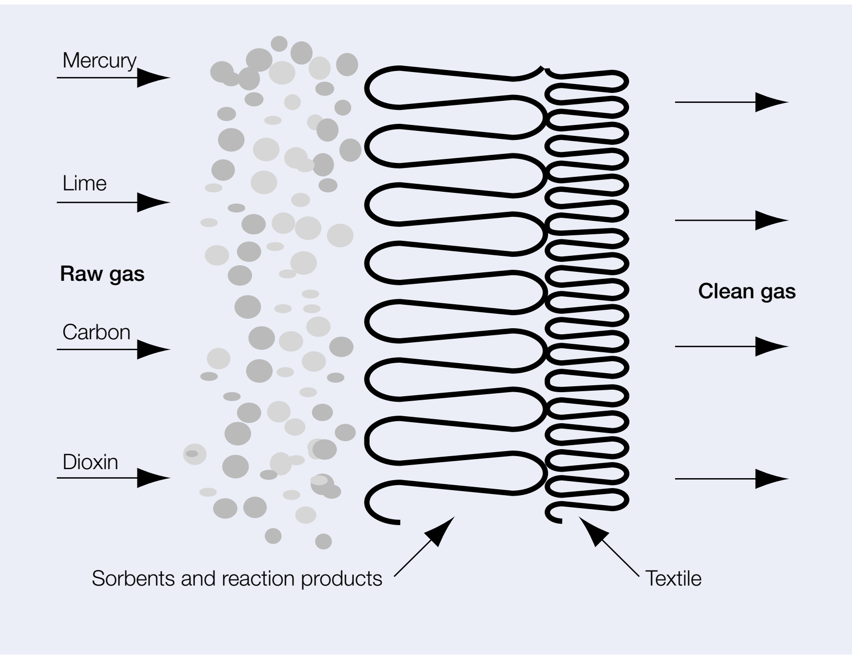
In its proposal, ABB Fläkt Industri suggested installing a Filsorption II stage in place of the wet electrostatic precipitator. The process of filsorption – which takes its name from filtration and adsorption – involves complex reactions between impurities in the flue gas and fine additives on the bags of a fabric filter **2**.

The advantage of filsorption over a wet electrostatic precipitator (WESP) is that it ensures the almost complete removal of not only the smallest solid particles but also several of the gaseous elements. These are removed by chemical reaction, absorption and adsorption in the filter cake, which consists of additives, reaction products and particles from the combustion process. The use of finely ground additives ensures a very large contact area.

The process is especially efficient at removing sulfur trioxide (SO_3). As there is almost no SO_3 downstream of the filsorption unit, ammonium salts cannot form even at low temperatures. This allowed the catalyst temperature to be set as low as 235–240 °C, making it possible for the plant’s own steam to be used to heat the flue gas to its final temperature before ammonia injection, which is cheaper than using an alternative fuel such as natural gas. Since almost 100 % of the solids are removed – most of them in the filter cake – there is normally no need to clean the catalyst and heat-exchanger. The operating prin-

'Lucerne 2000' waste-to-energy power plant with new Air Pollution Control system from ABB Fläkt **1**

Principle of filsorption, in which complex reactions take place between impurities in the flue gas and the fine additives on the bags of the fabric filter **2**



ciple of the Total Cleaning Concept developed by ABB Fläkt is shown in **3**.

Various finely ground additives are suitable. The most commonly used, a blend of hydrated lime and coal/carbon, was also chosen for the Lucerne plant. The advantages of such a mixture are as follows:

- The hydrated lime removes the acidic gases, including SO_3, remaining after the wet scrubber.
- The fine coke/carbon powder ad/absorbs the chlorinated hydrocarbons and in particular the dioxins and gaseous heavy metals, especially mercury.
- The filter cake (mainly consisting of additives) is very efficient at removing the submicron particles. As the most volatile heavy metals (Pb, Cd, etc) bond to the removed particles, emissions of these toxic elements are almost zero.

Fine coke/carbon powder is combustible if not handled with care. This potential hazard is minimized by mixing the carbon/coke with an inert material (eg, hydrated lime) and adopting a special design for the filsorption stage.

Apart from the technical advantages of the solution with filsorption, the total cost of the Air Pollution Control (APC) system **4** installed in Lucerne was also lower than that of the alternative solution with a wet electrostatic precipitator. This cost saving was evaluated as follows:

- Installation costs are lower due to the cheaper wet scrubber, which is designed to remove only HCl and SO_2), and the SCR-denox unit, which operates at a lower temperature.
- Operating costs are lower on account of the low pressure drop across the wet scrubber (an open spray type), smaller heat-exchanger around the SCR-denox unit, and lower cost of the final heating, due to the use of steam instead of natural gas.

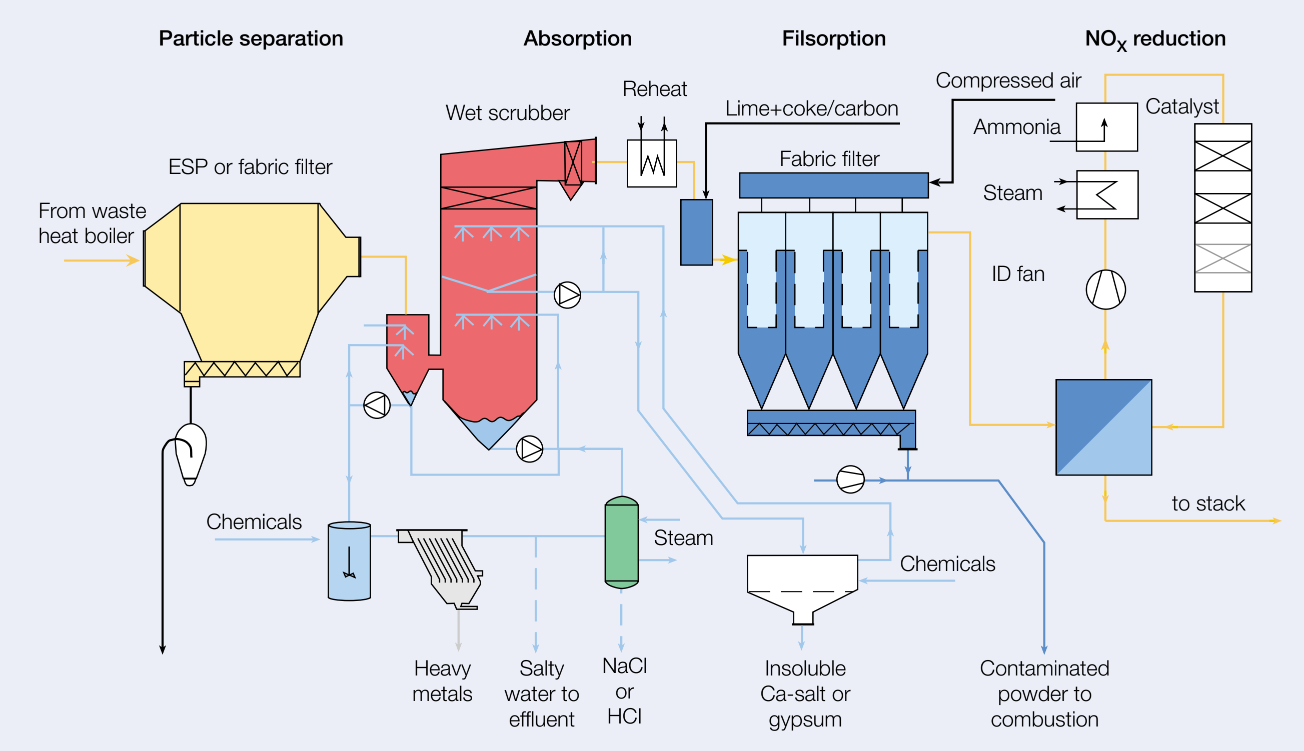


ABB Fläkt 'Total Cleaning Concept'

3

Flow diagram of the Air Pollution Control system installed in the waste-to-energy plant at Lucerne, Switzerland

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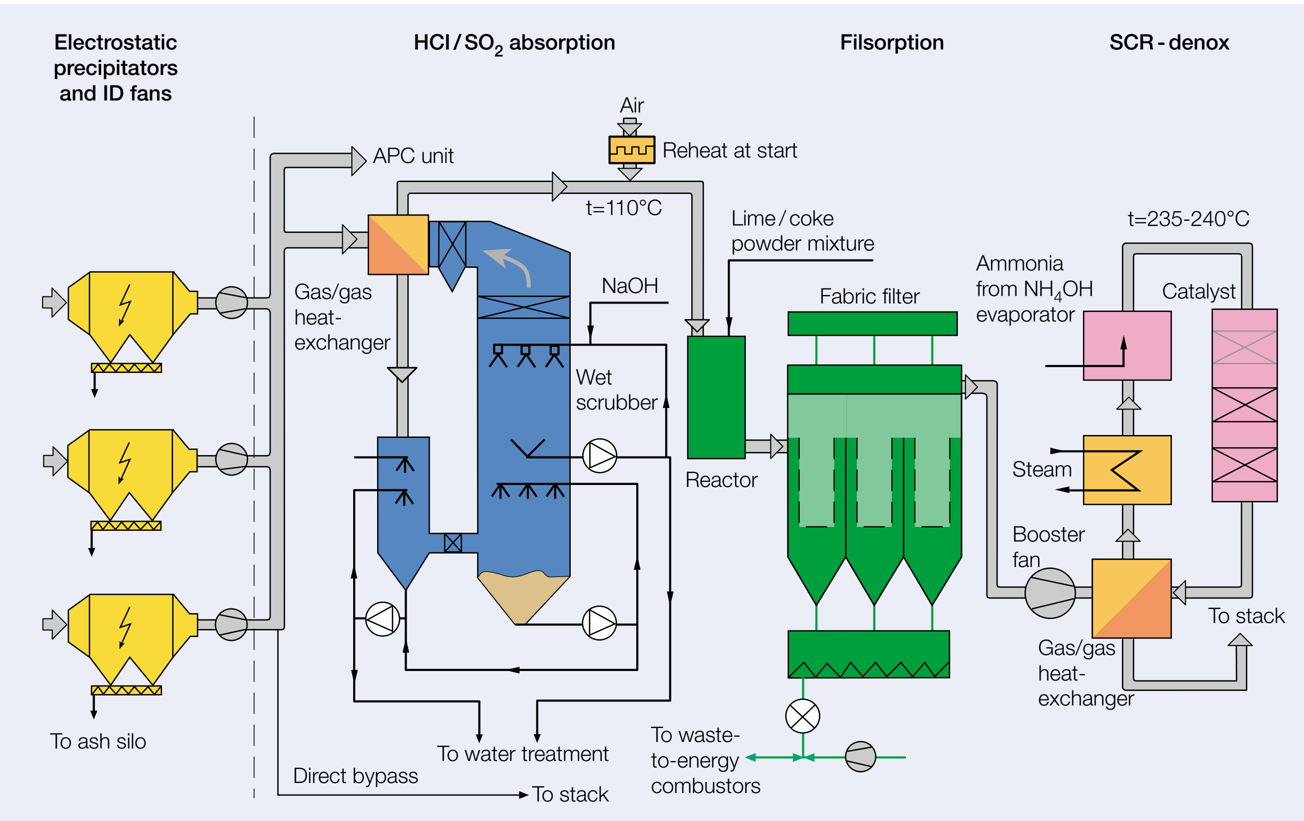
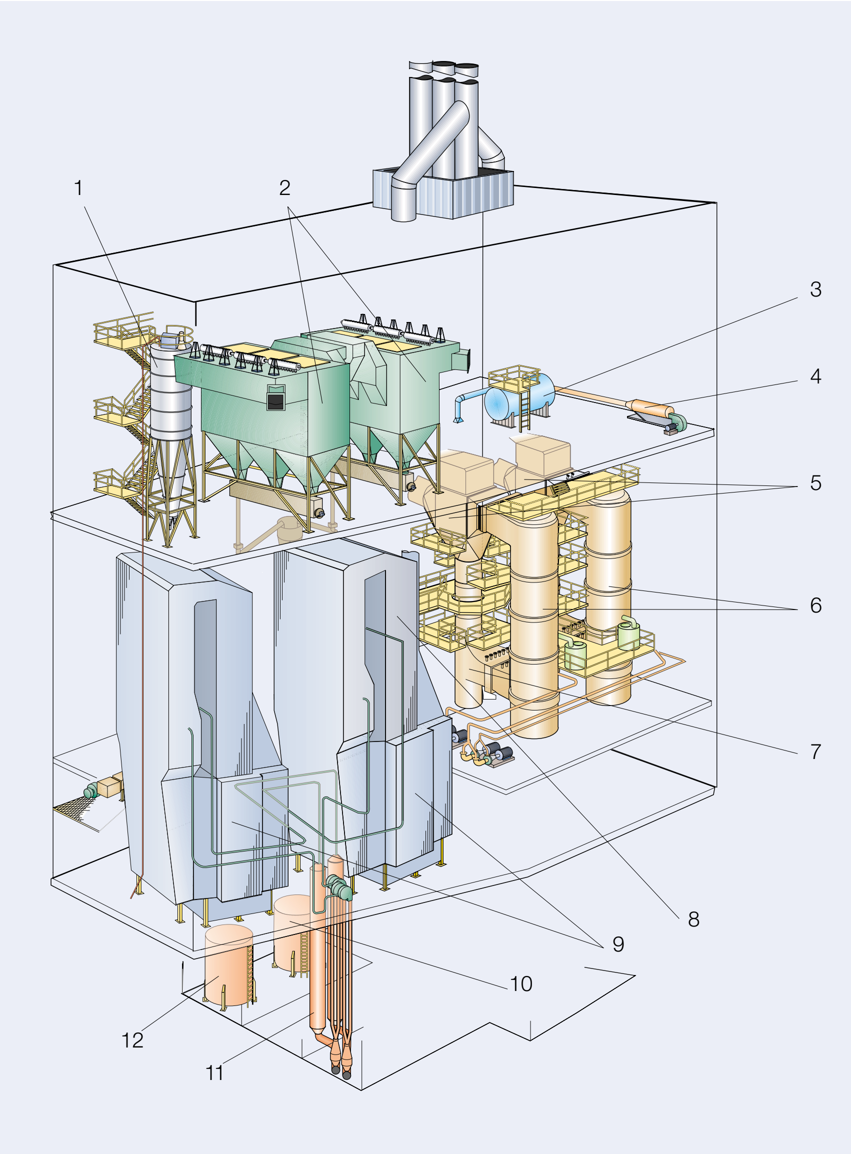




The new APC installation at Lucerne 5

1 *Lime/coke silo*
2 *Fabric filter*
3 *Emergency water tank*
4 *Heating*
5 *Gas/gas heat-exchangers*
6 *Wet scrubber*
7 *Quench*
8 *Catalyst*
9 *Gas/gas heat-exchangers*
10 *NaOH tank*
11 *Evaporator for ammonia*
12 *Ammonia storage*

Last but not least, better emission guarantees could be offered with the filsorption solution than with wet electrostatic precipitators.

Air Pollution Control

Features of the chosen APC solution include:

- Original ESP and ID fans for each combustor/boiler. The pressure in the combustors is controlled individually by the ID fans.
- The flue gases pass from the three ID fans to a common duct to which the two new, identical APC systems are connected.

Each of the two new APC systems 4, 5 in Lucerne comprises:

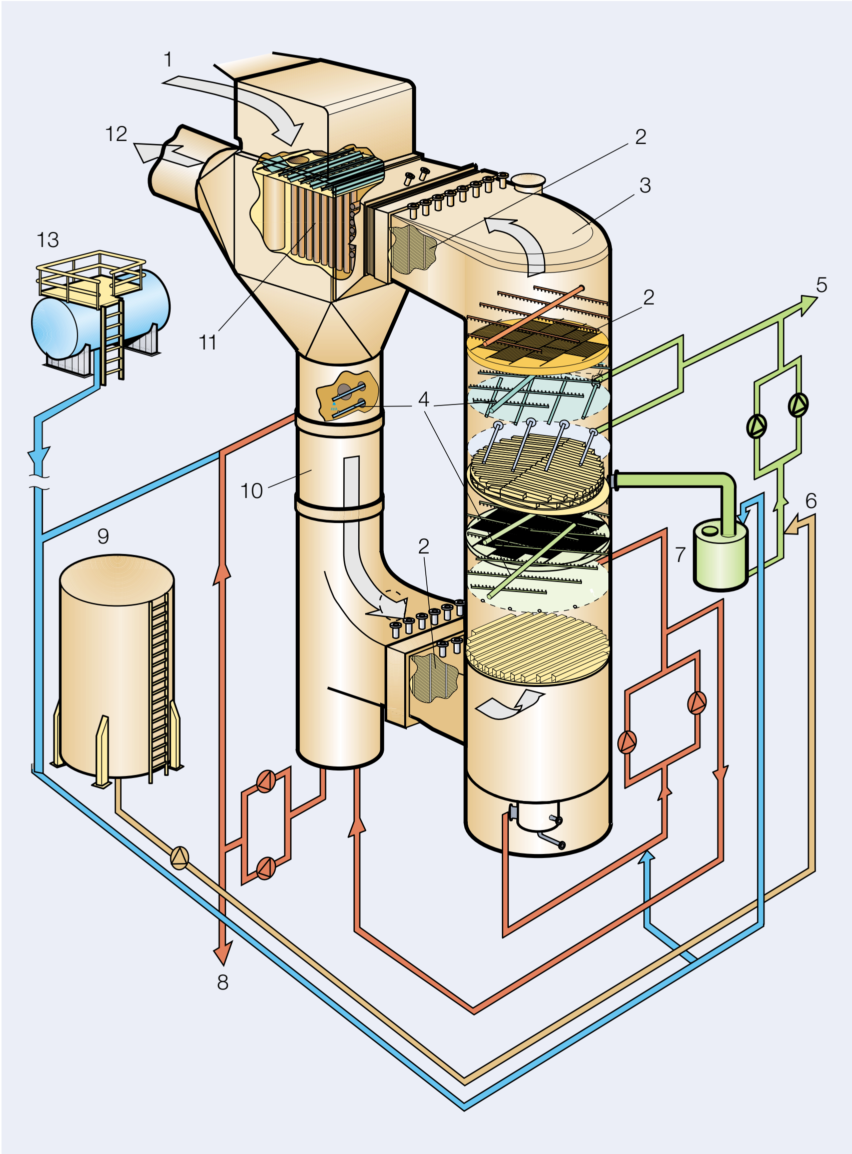
- A gas/gas Teflon heat-exchanger transferring heat from the inlet wet scrubber to the outlet. The wet scrubbers 6 have a separate quenching stage and a two-stage scrubbing process – one acid stage, mainly for HCl removal, and one neutral stage for the SO_2 absorption. A two-stage mist eliminator in the outlet guarantees a very low droplet concentration.

  The pressure drop across the open spray wet scrubber is very low. The technology used is highly reliable, being based on experience with some 100 installations, mainly involving waste-to-energy and soda recovery boilers.
- The filsorption stage 7 downstream of the wet scrubber. As this is a dry process, the saturated gas from the wet scrubber has to be heated. A heat-exchanger that uses heat from the inlet is therefore installed over the scrubber. The filsorption stage comprises:
  - A reactor for mixing the dry, finely ground additives into the flue gas.
  - A special filsorption fabric filter for filtration, sorption and chemical reaction. This filter has vertical inlet ducts and steep hoppers to prevent dust and powder deposits in which fires could smoulder. Powder and impurities in the flue gas are distributed over the entire filter surface by special inlet and gas distribution arrangements. Each fabric filter has three compartments with inlet and outlet dampers that allow them to be inspected individually during full-load operation.

    The filter bag material is Dralon T (PAC). The bags are cleaned on the clean-gas side, row by row, by air pulses generated by fast membrane valves connected to a tank with air compressed to 1 – 2 bar. Inspection and changing of the bags is also carried out on the clean-gas side **8**.

The dust removed as a result of the pulsing is collected by a screw conveyor below the filter, transferred to an intermediate silo and transported to the waste-to-energy combustors. The high operating temperature of the combustors destroys the organic matter (eg, dioxins), while the excess of hydrated lime removes some of the SO_2. Mercury released at the high combustion temperature is removed in the wet scrubber, which acts as the main sink for Hg.

- A booster fan, which transports the gas through the new APC system, is installed downstream of the filsorption stage. Since the flue gas is dry, very clean and at a low temperature of about 110 °C, this fan operates with very high efficiency. It is controlled such that a constant pressure is maintained upstream of the wet scrubbers. As the fan is located before the SCR-denox unit, this part of the APC operates at an overpressure and is therefore gastight.
- Catalyst for NO_x reduction **9**. This works with ammonia and operates at about 240 °C. As a result, the flue gas from the filsorption stage and the ID fan must first be heated. This is done in two steps:
  – First the gas is heated from 110 °C to 210–215 °C in a gastight gas/gas pipe heat-exchanger **10**. The hot side of the heat-exchanger is connected to the exit of the catalyst with an inlet temperature of 235 to 240 °C. As the gas is very clean and dry, cleaning of the heat-exchanger is normally not necessary.
  – Final heating of the flue gases upstream of the catalyst takes place with steam at a temperature of 370 °C and a pressure of 35 bar.



Wet scrubber installed in the Lucerne waste-to-energy plant **6**

1 *From ESP*
2 *Mist eliminator*
3 *Wet scrubber*
4 *Nozzles*
5 *Wastewater treatment*
6 *NaOH*
7 *Intermediate tank*
8 *Waste water treatment*
9 *NaOH tank*
10 *Quench*
11 *Heat-exchanger*
12 *To filsorption unit*
13 *Emergency water tank*

This is provided by the main waste-to-energy boilers in the second heat-exchanger. The hot condensate is recovered and converted to low-pressure steam.

The ammonia, which is stored as a water solution, is passed through an evaporator before being evenly distributed in the duct upstream of the catalyst. The two-layer catalyst is placed in a separate duct, through which the gas flows vertically downwards. During plant shutdowns, the catalyst is kept dry and then heated before the process is restarted. The cold flue gas is by-

Table 1:
APC system for the waste-to-energy plant at Lucerne. Inlet conditions and emission values stipulated by Swiss law and guaranteed by the Total Cleaning Concept

Element concentration per m^3 (normal conditions dry gas, 11 % O_2)		Normal/max. concentration at inlet of new APC system	Emissions: Swiss regulations	Emissions: Guaranteed
Dust	mg	35/50	10	2
$(Zn+Pb)_{tot}$	mg	17/25	1	0.2
Cd_{tot}	mg	0.5/l	0.1	0.01
Hg_{tot}	mg	0.5/l	0.1	0.01
HCl	mg	1,000/2,000	20	1
SO_2	mg	450/1,000	50	10
HF	mg	10/30	2	0.2
NO_x	mg	400/500	80	60
NH_3	mg	–	–	5
Dioxin I – TEQ	ng	3/5	–	0.05

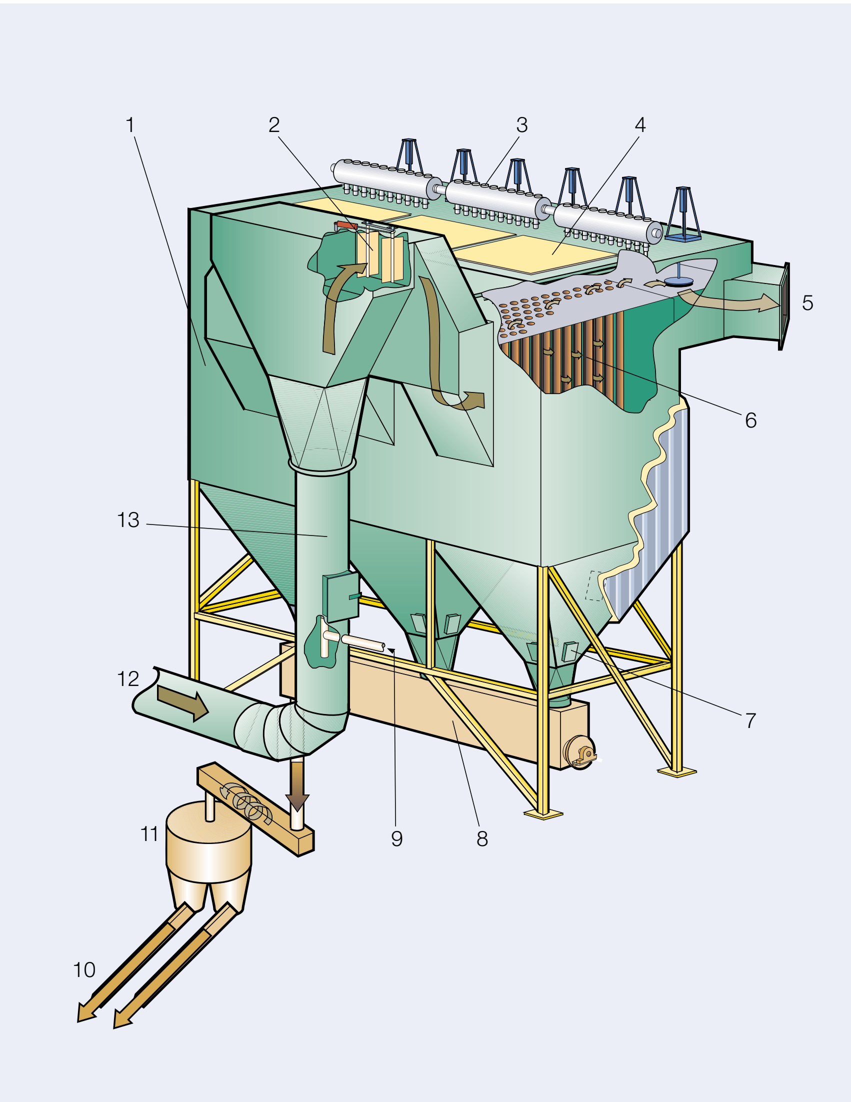
passed to the stack during the start-up.

The extremely clean conditions ensure long service lives for the catalyst and heat-exchangers.

The site space available for the new APC system was very limited. It is installed in a new 40-m high building, on the top of which there are three new stack pipes.

Environmental aspects

With all three boilers in operation, 11 to 13 t of waste can be burnt per hour. Each of the two new parallel APC systems is



Filsorption stage at the Lucerne plant **7**

1 *Fabric filter*
2 *Inlet dampers*
3 *Tank for compressed air*
4 *Inspection doors*
5 *To SCR-denox*
6 *Filter bags*
7 *Filter hopper*
8 *Screw feeder*
9 *Injection of lime/coke powder*
10 *To waste combustors*
11 *Residue silo*
12 *From wet scrubber*
13 *Reactor*

designed to handle 60 percent of the total flow of approximately 90,000 m^3n/h. The guaranteed emissions to the atmosphere are summarized in *Table 1*.

Guarantees were also given for the wastewater flow and the concentrations of impurities in the wastewater passing from the scrubber to the wastewater treatment plant.

Table 2:
APC system installed at the Lucerne waste-to-energy plant. Results from emission measurements and guaranteed values

Element	Emissions Line 1	Emissions Line 2	Guarantee
Dust	0.2	0.1	2
$(Zn+Pb)_{tot}$	<0.001	<0.001	0.2
Cd_{tot}	<0.001	<0.001	0.01
Hg_{tot}	0.001	0.001	0.01
HCl	0.01	0.01	1
SO_2	2.0	0.8	10
HF	<0.01	<0.01	0.2
NO_x	60	60	60
NH_3	0.3	0.2	5
Dioxin I – TEQ	<0.01	<0.01	0.05

All concentrations are given in mg/m^3 for normal dry gas, 11 % O_2, except for dioxins, which are given in ng. The results shown are mean values based on 2–6 measurements.

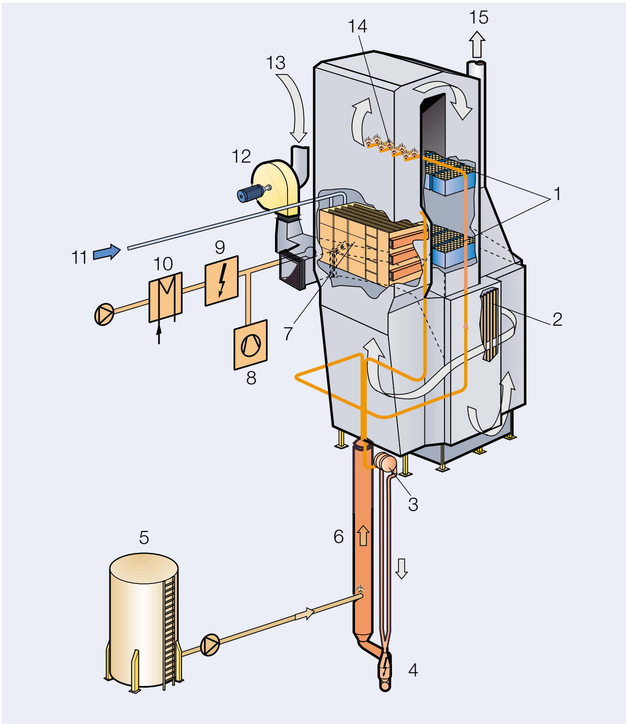
Guarantee measurements

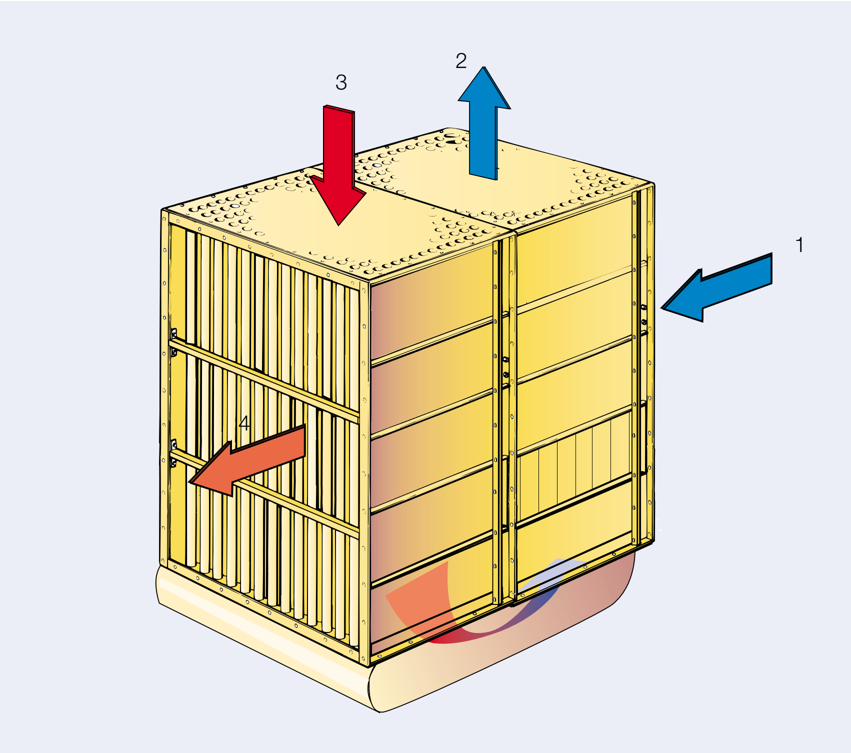
The guarantee measurements were carried out in August 1996 with the boilers operating close to normal conditions. Performed in accordance with ISO or VDI standards, the measurements also confirmed that all the guarantees concerning the consumption of chemicals

The filter bags are inspected and replaced working from the clean-gas side. An easy-to-use mechanism allows the filter bags to be changed quickly. **8**

Catalyst with heat-exchangers installed in the Lucerne waste-to-energy plant **9**

1 *Catalyst*
2 *Gas/gas heat-exchanger*
3 *Fan for NH_3 evaporation*
4 *Heater*
5 *Ammonia/water tank*
6 *Evaporator*
7 *Final heating*
8 *Dehumidifier*
9 *Electrical air heater*
10 *Steam air heater*
11 *Steam*
12 *Flue gas fan*
13 *From Filsorption unit*
14 *Injection of gaseous ammonia*
15 *To stack*





Fläkt QGB gas/gas heat-exchanger for preheating the gas passing to the SCR catalyst **10**

1 *Flue-gas inlet*
2 *Clean flue gas to stack*
3 *From catalyst*
4 *Flue gas to catalyst*

are satisfied with a good margin of safety.

Electrical power consumption was measured at 400 kW, or 35 kWh/t of burnt waste (ie, 60 percent of the guaranteed value). The flow of wastewater from the scrubber and the impurities in the wastewater were lower than estimated. *Table 2* gives the results of the emission measurements.

Operating experience

The APC plant was started up on schedule and has been operated continuously ever since. Some improvements have been carried out on the basis of the available experience. For example, ejectors have been installed for the dust transport from the intermediate silo below the filsorption filter to the waste-to-energy combustors. Also, the wastewater flow from the scrubbers to the treatment plant, which was originally controlled by the conductivity of the scrubber water, varied too much for efficient water treatment and had to be modified. The membranes of the level indicator/controller in the quenchers have been replaced with new ones made of tantalum, a material which is better able to withstand the very aggressive atmosphere in these units.

Since going on stream, 'Lucerne 2000' has proved to be a reliable and very cost-effective solution to the problem of air pollution control at waste-to-energy plants.

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