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EXPERIMENTAL FIRING WITH BRINI, AT EKSJÖ, APRIL 1981

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SUMMARY

Experimental firing with BRINI pellets, which are made from the combustible fraction of household waste, has been carried out in a 10 MW fluidised bed combustion boiler.

The results indicate that good combustion efficiency was obtained. Emission of polynuclear aromatic hydrocarbons was low. Release of chlorinated organic compounds and dust emission were also at a low level.

Experiments to study the effect of firing with a mixture of BRINI and wood chips, in order to reduce HCl emission, were not conclusive because of difficulties in mixing the fuels.

CONTENTS

1. BACKGROUND AND OBJECTIVES

As a result of the increasing cost of fossil fuels, there has been growing interest in recent years, in the use of waste materials for the production of energy.

Burning of unsorted household waste can, however, result in certain problems. The presence of non-combustible material, glass, metals etc. causes the formation of troublesome slag. Problems may arise in feeding the material to the furnace.

The difficulty in obtaining the ideal conditions for combustion, together with the composition of the fuel, may lead to serious emissions of organic pollutants, hydrochloric acid, dust and metals.

These disadvantages can be reduced by sorting the waste material into a number of fractions. The BRINI system, developed by PLM Miljöteknik AB, is based on the principle of separating the waste into three separate fractions:

- combustible material, 40-50%
- compost raw material, 35-45%
- residue, 15%

The energy-rich components of the waste are concentrated in the fuel fraction, from which the materials liable to cause environmental contamination have, to a great extent, been separated.

Fig. 1 shows a diagram of the BRINI system.

Earlier investigations showed that emission of pollutants was lower when BRINI was burned, compared with unsorted waste. There has been, however, a lack of knowledge on emission of organic compounds; HCl emission is not fully understood.

In view of this background, PLM Miljöteknik AB and IVL commenced experimental work with the object of documenting the combustion of BRINI under various conditions. The effect on HCl emission of firing with a mixture of BRINI and wood chips was also included in the investigation.

2. EXPERIMENTAL PROCEDURES

Experimental firing was carried out in a 10 MW fluidised bed combustion boiler, supplied to Eksjö District Heating Station, by Generator Industri AB. Fig. 2 shows a diagram of the layout of the boiler. The fuel is tipped into a storage hopper and is fed from the hopper to a conveyer by a Parascrew feeder. It then passes through a buffer stock hopper and is fed into the boiler. The combustion bed temperature is allowed to fluctuate between 750° and 950°C. During the actual firing trials the temperature was 870° - 900°C. The cooled flue gas, at 170°C, first passes through a coarse dust cyclone separator, and then through a textile filter.

The experimental firing was carried out between 13.4.81 and 15.4.81. The average consumption was 1.8 tonne BRINI per hour, corresponding to a power of 8.1 MW. A total of 43 tonne BRINI was burned.

The boiler was designed for low calorific value fuel with a moisture content of 40-60%. This means that only a small cooling surface around, or in the combustion bed, is required in order to keep the bed temperature at the correct level, at a given excess air supply rate.

When firing with BRINI, which has a moisture content of approximately 10% and a calorific value of approximately 18.8 MJ/kg (i.e. approximately double that of wood chips), the combustion bed temperature can be kept within the upper limit by raising the level of the bed and by using a greater excess of air than normal. As a result of the relatively low flue gas temperature and the low combustibles content in the ash, the efficiency during the test period was as high as 88%.

Experiments were also carried out using a mixture with wood chips. However, because of certain technical difficulties in supplying the chips, a mixture containing about 9% of chips was the highest obtained.

3. SAMPLING

3.1 Organic components

An iso-kinetic flow of approximately 4 Nm^3/h was drawn out using a glass sampling apparatus, as shown in Fig. 3. Particulate matter was collected on a glass-fibre filter. After cooling in a water-cooler unit, with separation of the condensate, the non-condensable components were collected on a polymeric adsorbent, XAD-2. The samples were taken after passage through the textile filter.

3.2 Inorganic components

HCl Samples were removed both before and after the textile filter, in order to determine any HCl absorbing properties of the separated dust.
Fig. 6 shows the sampling apparatus used.

Mercury was absorbed in a permanganate solution acidified with sulphuric acid.

Sulphur dioxide was absorbed in 2% H_2O_2 solution.

Carbon dioxide and carbon monoxide were measured continuously with an IR instrument.

NO_x was measured using the Dräger tube method.

4. ANALYSIS

The united extracts from the particulate matter, condensate and adsorbent were analysed as follows:

Total gas chromatograph separable components (tar content)

An aliquot portion of the total extract was evaporated to low volume and analysed on a OV-101, 110°-$300^{\circ}C$, $8^{\circ}C$/min. Hexacosane was used as internal standard. The total of gas chromatograph separable components is, therefore, given as hexacosane equivalents in mg.

Polynuclear aromatic hydrocarbons

Polynuclear aromatic hydrocarbons were determined by gas chromatography, on a capillary column. An aliquot portion of the total extract was evaporated and re-dissolved in cyclohexane. This solution was treated as described by Björseth (3).

Chlorinated benzene compounds

An aliquot portion of the total extract was evaporated to low volume and then re-dissolved in cyclohexane. This solution was cleaned by treatment with sulphuric acid (conc. H_2SO_4, with 7% SO_3). Chlorinated benzene compounds were determined by SIM analysis (single ion monitoring) M^+ $(M+2)^+$ fragment.

Chlorophenols

An aliquot portion of the total extract was evaporated and re-dissolved in iso-octane/diethyl ether (2:1). This solution was then liquid-extracted with 0.5 M NaOH solution. The chlorophenols in the NaOH phase were acetylated and determined by gas chromatography.

HCl

HCl was determined as chlorides, using an EEL Chloride Meter.

Ash content

Ash content was determined by incineration, for 12 h at 650°C.

Moisture content

Moisture content was determined by drying, for 12 h at110°C

5. RESULTS AND DISCUSSION

Table 1 shows a summary of the results obtained. The experiments indicate that when BRINI is burned in a fluidised bed combustion boiler, good combustion efficiency can easily be obtained. This results in low emission of those substances which are primarily dependent on the conditions of combustion. Determination of polynuclear aromatic hydrocarbons in the flue gases gave a low result, 2-3 µg/Nm^3 dry gas 10% CO_2. No measurable quantity of benzo (a) pyrene could be detected, Table 2.

Emissions of chlorobenzenes and chlorophenols were, respectively 5-7 and 12-59 µg/Nm^3 dry gas 10% CO_2. These figures should be compared with 3-110 and 70-500 µg/Nm^3 dry gas 10% CO_2, respectively, which are the results obtained when unsorted household waste is burned (1).

Dust emission was very low. Two samples were taken; both gave a result of 12 mg/Nm^3 dry gas 10% CO_2. Dust content before the textile filter was around 2500 mg/Nm^3 dry gas 10% CO_2. Analysis of the dust showed a content of less than 2% combustible material.

Fig. 4 shows a comparison between the emissions of various substances when a number of different fuels are burned. The areas of the triangles correspond to the quantity emitted.

The level of HCl released was somewhat higher than had been expected, at ∿ 350-400 mg/Nm^3 dry gas 10% CO_2. No difference was observed when wood chips were mixed with the fuel; the proportion of wood chips, 9%, was presumably too low to produce any effect. It is difficult to explain the rather lower HCl content before the textile filter, compared with the content after the filter.

The level of mercury released was 5-6 µg/Nm^3 dry gas 10% CO_2. Firing with unsorted household waste gives 139 µg/Nm^3 dry gas 10% CO_2.

In conclusion, it can be said that BRINI is convenient to use and gives low emission of organic pollutants. The low moisture content of 8%, and presumably also the design of the boiler,were favourable factors in giving the results that were obtained.

6. LITERATURE REFERENCES

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Experiment No.	1	1	2	3 1) ↔ 4 2)	5 1) ↔ 6 2)	7 1) ↔ 8 2)	9 1) ↔ 10 2)
Date	14.4	14.4	13.4	14.4	14.4	14.4	14.4	14.4	15.4	15.4	15.4	15.4
Flue gas temperature, °C	173	173	173	173	173	173	173	173	173	173	173	173
Flue gas flow rate, Nm^3 dry gas/h	13000	13000	12000	13000	13000	13000	14000	14000	14000	14000	14000	14000
CO_2, % vol.	10.3	10.3	9.8	10.3	10.8	10.8	10.9	10.9	12.0	12.0	11.3	11.3
CO, ppm	500	500	700	550	450	450	400	400	500	500	300	300
NO_x, ppm	120	-	-	-	-	-	-	-	-	-	-	-
Sampling time, h	3.2	2.5	1.5	2.2	1.5	1.5	1.0	1.5	1.3	1.5	2.1	2.0
SO_2, mg/Nm^3 dry gas 10% CO_2	196	131	-	-	-	-	-	-	-	-	-	-
HCl, " " " " "	-	-	286	345	510	65	370	77	470	235	310	210
Water-soluble chlorides mg/Nm^3 dry gas 10% CO_2	-	-	1	47	7	560	4	3	12	17	21	95
Dust content mg/Nm^3 dry gas 10% CO_2	12	12	-	-	-	3010	-	2030	-	1940	-	1910
Total extracted quantity mg/Nm^3 dry gas 10% CO_2	0.1	0.1										
Mercury, µg/Nm^3 dry gas 10% CO_2	5.5	6.0	-	-	-	-	-	-	-	-	-	-
Σ Chlorophenols " " " " "	12	59	-	-	-	-	-	-	-	-	-	-
Σ Chloroguaiacols " " " "	<0.04	0.1	-	-	-	-	-	-	-	-	-	-
Σ Chlorobenzenes " " " " "	4	7	-	-	-	-	-	-	-	-	-	-
ΣPAH, " " " " "	1.3	2.5	-	-	-	-	-	-	-	-	-	-
Benzo(a)pyrene " " " " "	<0.04	<0.04	-	-	-	-	-	-	-	-	-	-
BRINI, ash content %	7	-	-	-	-	-	-	-	-	-	-	-
BRINI, moisture content %	8	-	-	-	-	-	-	-	-	-	-	-
Wood chips, moisture content, %	21	-	-	-	-	-	-	-	-	-	-	-
Wood chips, proportion in mix,%	-	-	-	-	-	-	-	-	-	-	-	-
Separated dust									9	9	9	9
Σ Chlorophenols, µg/kg	14	-	-	-	-	-	-	-				
Σ Chloroguaiacols, "	<9	-	-	-	-	-	-	-	-	-	-	-
Σ Chlorobenzenes, "	55	-	-	-	-	-	-	-	-	-	-	-
Σ PAH "	70	-	-	-	-	-	-	-	-	-	-	-
Ash content %	98	-	-	-	-	-	-	-	-	-	-	-

1) After textile filter 2) Before textile filter

Table 1

Table 2 Polynuclear aromatic hydrocarbons

	µg/Nm^3 dry gas 10% CO_2		µg/kg
	Exp. 1	Exp. 2	Separated dust
Acenaphthylene	0.07	0.4	<22
Acenaphthene	<0.08	*	<22
Dibenzofurane	0.7	0.9	<22
Fluorene	0.2	0.3	70
9-Methylfluorene	<0.05	<0.08	<22
9,10-Dihydroanthracene	<0.05	<0.08	<22
2-Methylfluorene	-	-	-
1- "	<0.04	<0.08	<22
Dibenzothiophene	<0.04	<0.08	"
Phenanthrene	*	*	"
Anthracene	<0.05	<0.08	"
Acridine	"	"	"
Carbazole	"	"	"
2-Methylanthracene	"	"	"
1-Methylphenanthrene	"	"	"
9-Methylanthracene	"	"	"
3,6-Dimethylphenanthrene	"	"	"
1,2-Dihydropyrene	*	*	"
Fluoranthene	0.2	0.7	"
Pyrene	0.09	0.2	"
Benzo (a) fluorene	<0.05	<0.08	"
Benzo (b) fluorene	"	"	"
1-Methylpyrene	"	"	"
Benzo (a) anthracene	0.1	"	"
Chrysene	0.05	0.08	22
Triphenylene	"	"	"
Napthacene	<0.04	<0.08	<15
Benzo (b,o,k,)fluoranthene	"	"	"
Benzo (e) pyrene	"	"	"
Benzo (a) pyrene	"	"	"
Perylene	"	"	"
3-Methylcholanthrene	"	"	"
m-Quaterphenyl	"	"	"

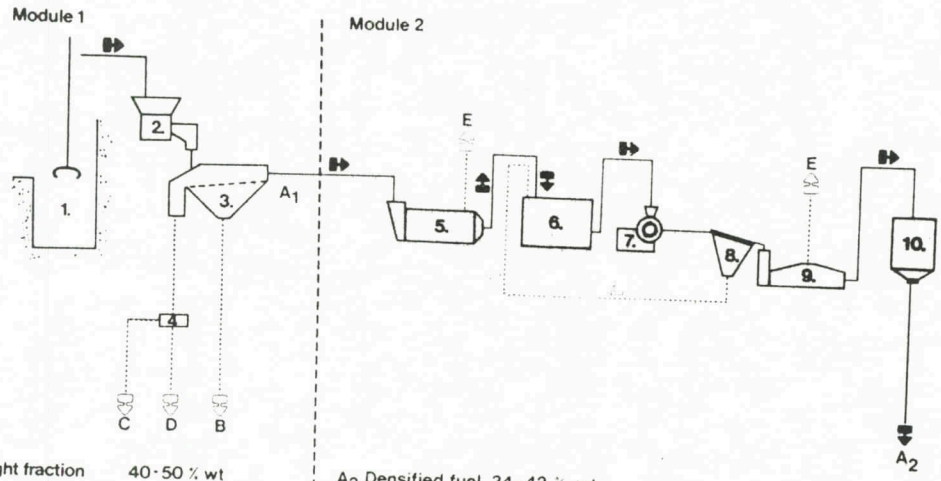
Table 2 (cont.)

	Exp. 1	Exp. 2	Separated dust
o-Phenylenepyrene	<0.04	<0.08	<15
Dibenzo(a,h)anthracene	"	"	"
Picene	"	"	"
1,2,3,4-Dibenzanthracene	"	"	"
Benzo(g,h,i)perylene	"	"	"
Anthanthrene	"	"	"
Σ PAH	1.3	2.5	70

* = Disturbance. Not possible to evaluate

Fig. 1

Flow sheet Refuse Derived Fuel (RDF) - The PLM BRINI system



A_1	Light fraction	40 - 50 % wt
B.	Screen fraction	35 - 45 % wt
C.	Magnetic material	5 % wt
D.	Reject	10 % wt

1. Bunker with overhead travelling crane
2. Shredder
3. Ballistic classifier
4. Magnet

A_2	Densified fuel	34 - 42 % wt
E.	Vapour	6 - 8 % wt

5. Dryer
6. Metering box
7. Pelletizer
8. Screen
9. Cooler
10. Storage bin

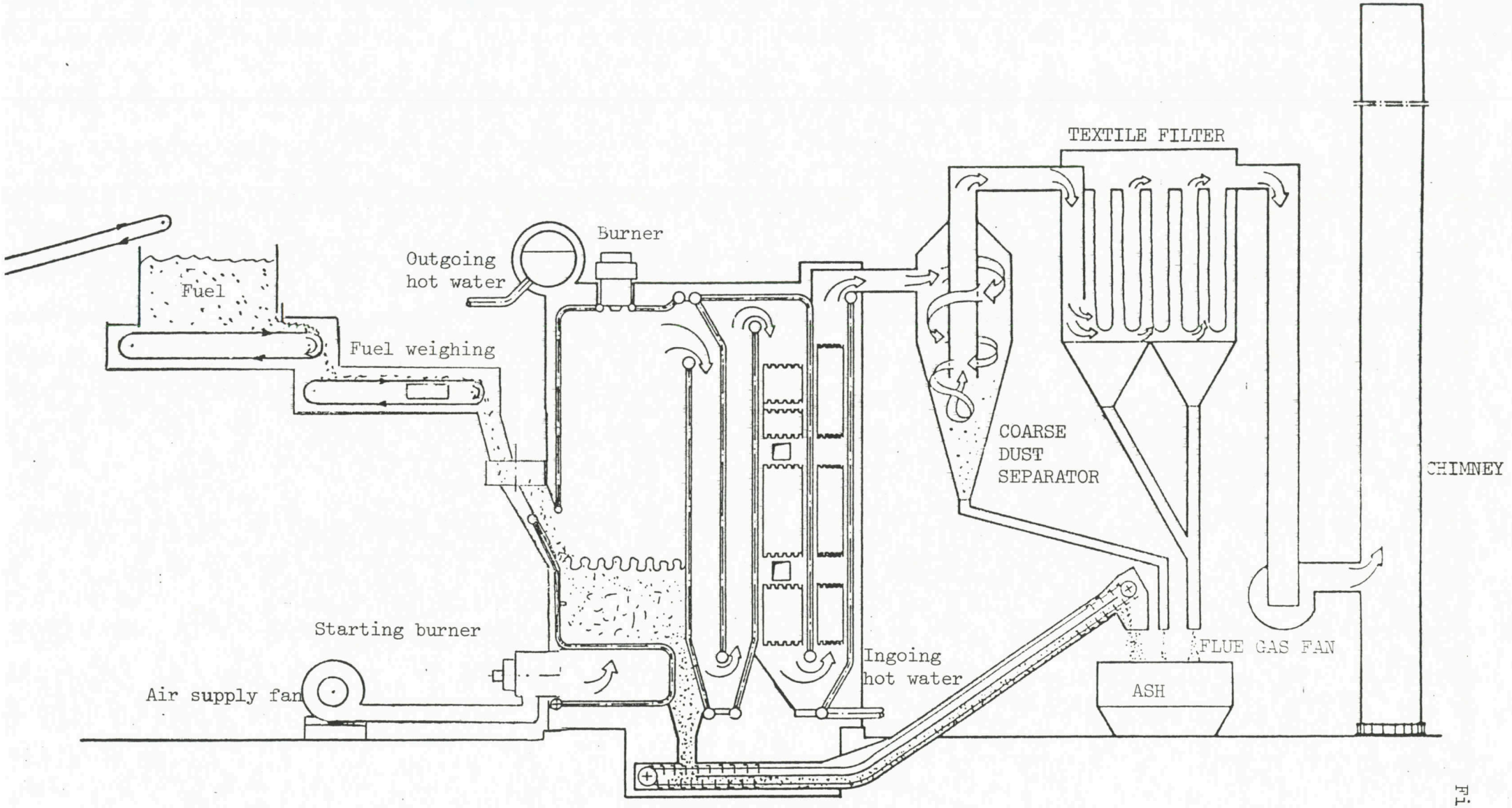


Fig. 1 Flow diagram showing principle of operation of 10 MW boiler, with fluidised combustion bed.

Fig. 2

Fig. 3

SAMPLING AND PROCESSING OF FLUE GAS SAMPLES

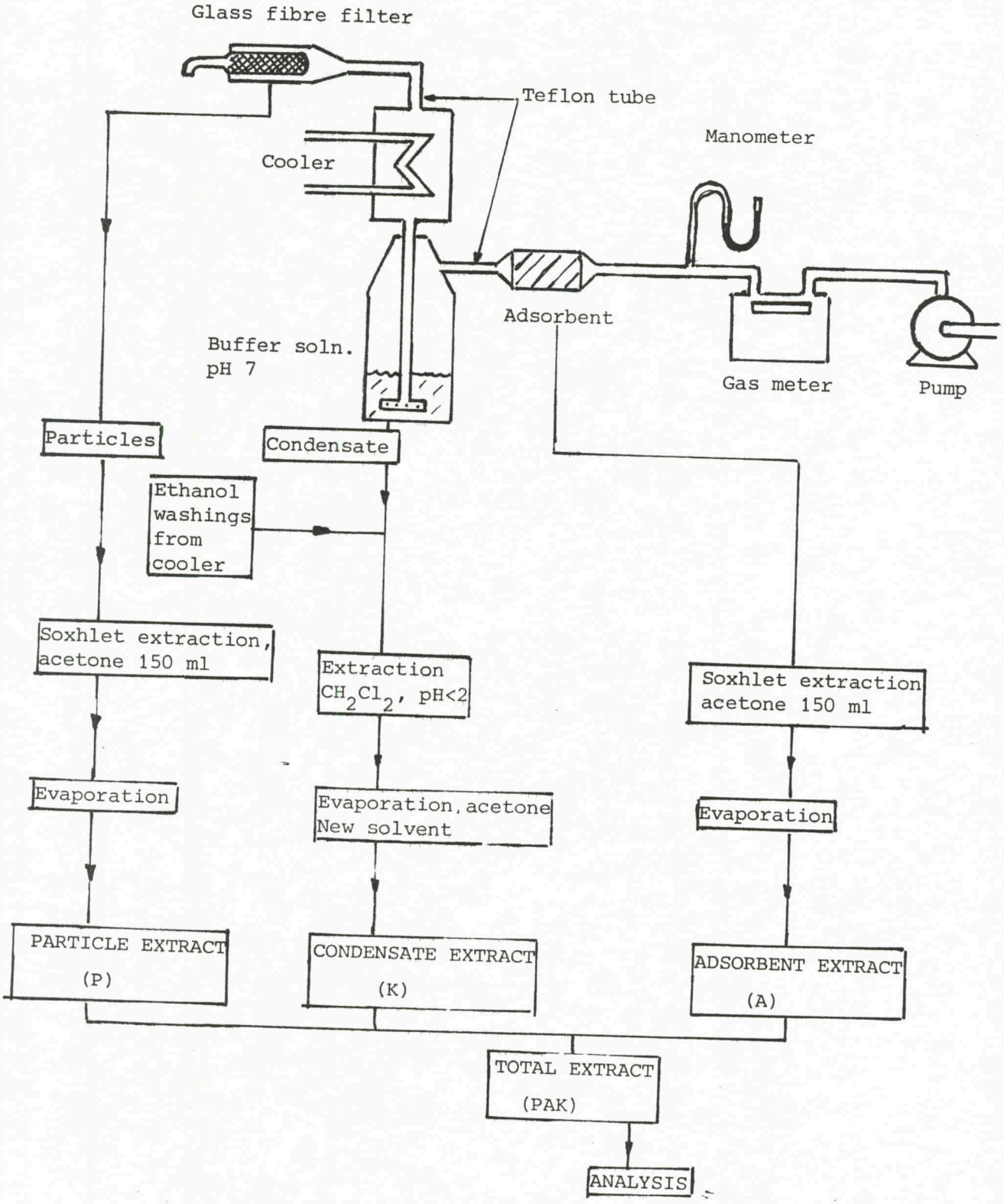


Fig. 4a

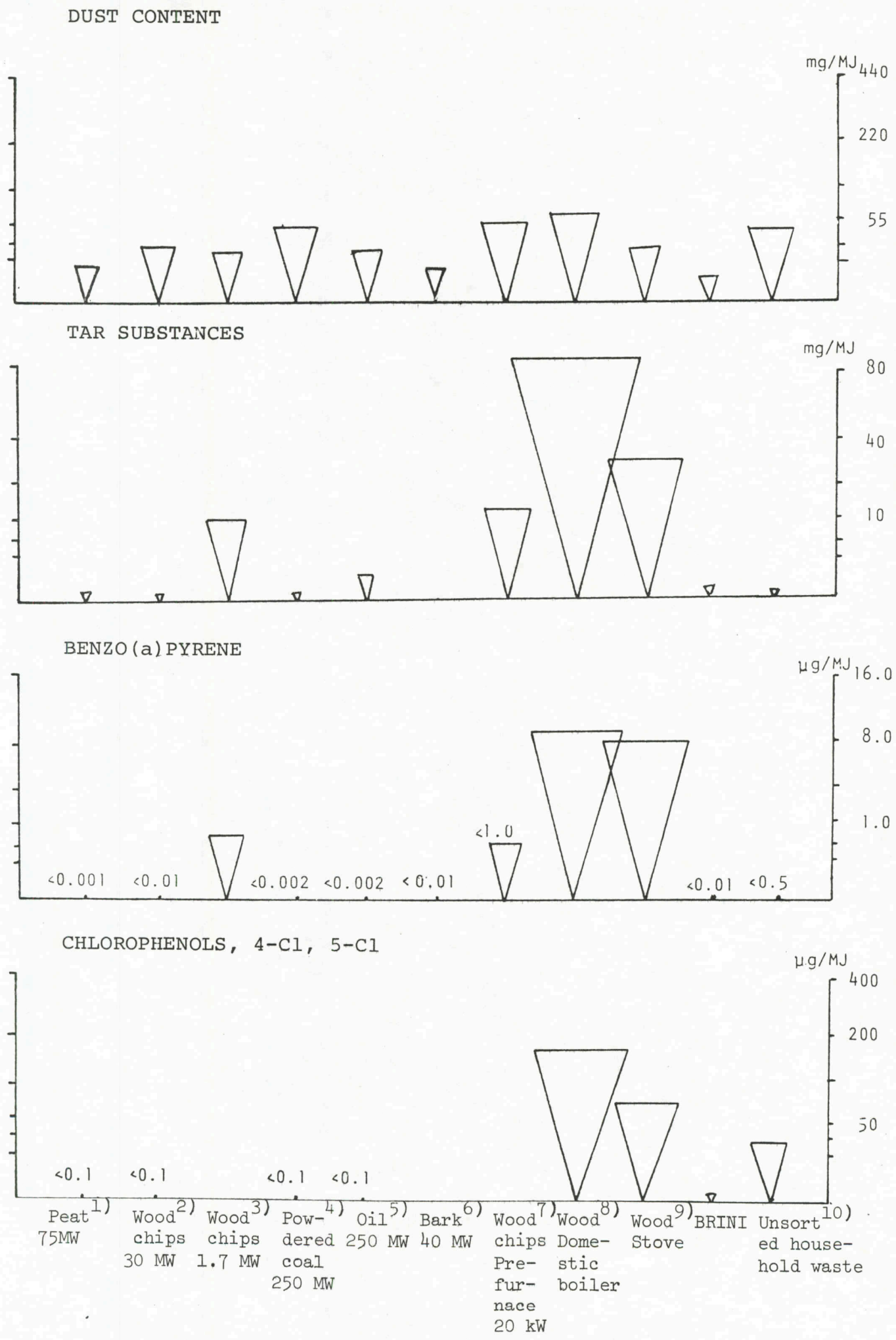


Fig. 4 Comparison of emissions from combustion of various fuels

Fig. 4b

1) Firing with powdered peat in district heating station (100 MW) with electrostatic dust filtration, Ref. 8.

2) Firing with wood chips in a cyclone pre-furnace (30 MW) with electrostatic dust filtration, Ref. 8.

3) Firing with wood chips on hearth, multi-fuel boiler 1.7 MW, with multiple cyclone dust separation, Ref. 8.

4) Firing with powdered coal, at Ingå power station (250 MW) with electrostatic dust filtration, Ref. 7.

5) Oil firing at Aros power station (250 MW) with electrostatic dust filtration, Ref. 7.

6) Firing with bark in a multi-fuel boiler (40 MW) with electrostatic dust filtration, Ref. 4.

7) Firing with wood chips in domestic boiler, with pre-furnace (20 kW), without dust separation, Ref. 9.

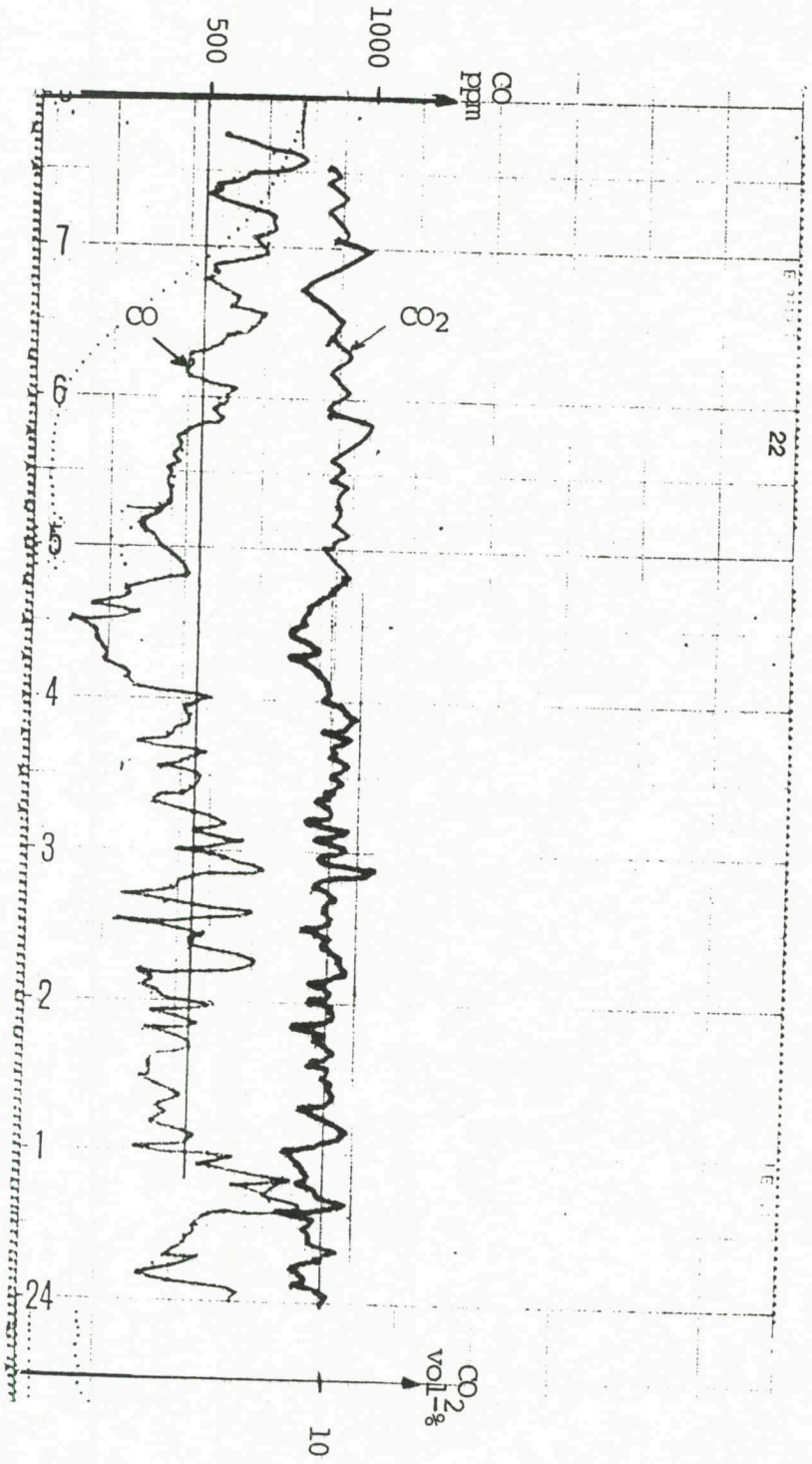
8) Firing with wood in domestic boiler, without dust separation, Ref. 9.

9) Firing with wood in domestic stove, without dust separation, Ref. 9.

10) Incineration of unsorted domestic waste, with dust separation by cyclone and electrostatic filter. Ref. 1.

Fig. 5

VARIATIONS IN CO AND CO_2 DURING EXPERIMENTS



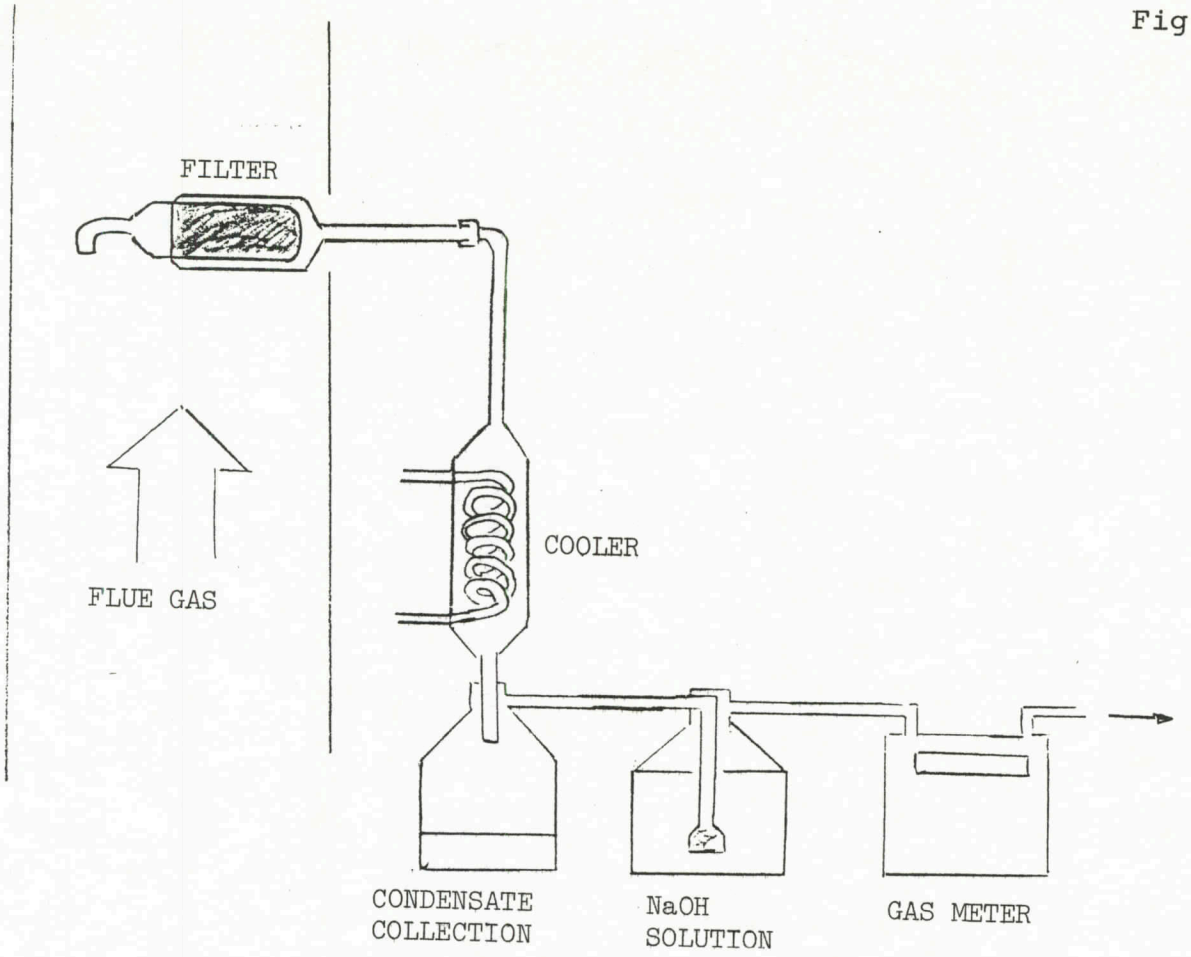


Fig. 6 Sampling system for hydrochloric acid