Proceedings of the 17th Biennial Waste Processing Conference
ASME 1996

SYNCOM - THE NEXT STEP IN MODERN MASSBURN TECHNOLOGY

Richard Scherrer
Engineering Department
Ogden Martin Systems, Inc.
Fairfield, NJ

Joachim Horn
Technology Department
Martin GmbH fuer Umwelt und Energietechnik
Munich
Germany

ABSTRACT

A well proven, environmentally sound method for the ultimate disposal of solid waste is a modern, stoker fired, massburn waste-to-energy facility. To meet the ever increasing demands to reduce air emissions and residues left for landfilling, a next generation combustion technology has been developed in Germany. The Syncom process (Synthetic Combustion) was developed to meet and exceed all existing or presently considered regulations and offers benefits expected from the next generation facilities in Europe. Existing massburn waste-to-energy technology consists of a stoker fired combustion system with heat recovery in a steam boiler and flue gas clean up in a sophisticated air pollution control system. Syncom adds to this the following main components:

- Oxygen enriched primary combustion air
- Flue gas recirculation (FGR) for secondary combustion air
- Infrared (IR) camera guided combustion control
- Fuzzy logic combustion control design

The resulting advantages over conventional approaches to massburn are:

- Flue gas quantity reduced by 40-50%
- Size of air pollution control equipment reduced by up to half
- Mass air emissions reduced by up to half
- Improved ash quality to ensure recyclability

The paper will describe the process in detail and contain tables and diagrams based on results obtained from full scale testing and comparing this advanced technology to the presently applied or considered regulatory requirements in Europe and the United States.

INTRODUCTION

Waste-to-energy facilities have been widely employed to solve the pressing problem of ultimate solid waste disposal. Worldwide they contribute considerable to overall waste management practices. Modern, stoker fired massburn facilities equipped with the appropriate air pollution control systems achieve very low air emission levels. During the 1980's and early 1990's allowable air emission levels and ash quality requirements were restricted significantly by the environmental regulatory authorities in the USA, Europe and elsewhere. While in the USA private companies build and operate these facilities and offer designs that while meeting the regulatory requirements, are also cost competitive, many European countries followed until very recent the practice to have consulting firms specify individual plant components. This led to often excessive costs for air pollution control equipment due to the fact that nearly all of the in the market place available pieces of equipment were simply included in the plant specification according to the principle that although it is not absolutely necessary, it cannot hurt to have it (belt and suspenders). The reality that even taxpayers money does not grow on trees and tipping fees reaching levels of 5 to 10 times comparable fees in the USA forced a rethinking and created a need to lower the cost of these facilities without compromising their ability to meet all emission control requirements. The hereafter described Syncom process is a way of improving the combustion conditions and at the same time reducing the amount of flue gas emitted from the stack. This has the dual benefit, that the size of the air pollution control equipment can be reduced and the mass emissions are reduced if the emission concentration levels are maintained as required by air pollution control regulations.

THE SYNCOM PROCESS AND ITS COMPONENTS

The following assumes, that the reader is familiar with the basic principles of the Martin or any similar European type massburn system and highlights only the actual changes to the “conventional” massburn technology.

Oxygen enriched primary combustion air

Primary combustion air (underfire air - UFA) constitutes in the order of 70% of the total combustion air. The other 30% are applied as secondary combustion air.

By adding oxygen to the primary combustion air to increase the O_2 content from the natural level of 21 vol.% to a level of 26-35 vol.% combustion on the stoker grate is intensified (Fig. 1). Fuel bed temperatures as measured by the IR camera increase about 150° K (270° F). No increase in the grate bar temperature results. The bars are protected by a consistent and stable layer of solid waste that protects them from the extreme radiation in the combustion chamber and are also cooled by the circulation of the combustion air through the inside of the bars.

Oxygen is produced on site with a pressure swing adsorption (PSA) plant which typically produces approx. 92% purity O_2 which is more than sufficient for this purpose. Even lower grades of purity would be acceptable.

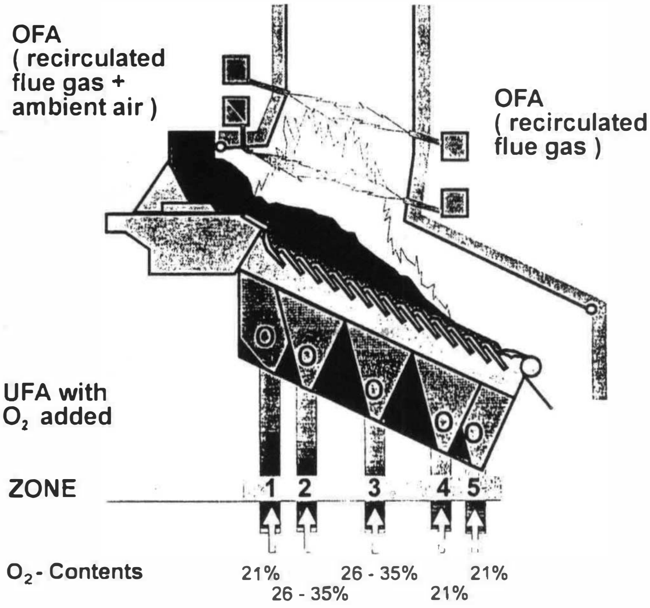


FIG. 1 O_2 - CONDITIONING OF COMBUSTION AIR

Flue gas recirculation for secondary combustion air

Secondary combustion air or overfire air (OFA) is injected through four rows of nozzles; two rows in the front and two rows in the rear wall of the waterwall enclosure of the combustion chamber. The individual nozzles in the two rows on each wall are arranged in an offset pattern (stitched). This so-called 4-row stitching arrangement assures full coverage of the furnace cross section and the turbulence needed for good mixing of the gases. The two levels of secondary air accomplish a staged combustion which in conjunction with flue gas recirculation reduces the generation of NO_x. Three of the four rows of OFA nozzles receive recirculated flue gas. The lower front wall row receives a combination of recirculated flue gas and ambient air (Fig. 1). Recirculated flue gas contains 6-9 vol.% O_2. The main purpose of the OFA is to mix with the unburnt combustion gases from the stoker grate and complete the combustion process. Due to the intense primary combustion and the 4-row stitching arrangement of the OFA nozzles this reduced oxygen content in the OFA is still sufficient to accomplish this task.

Camera guided combustion control

An infrared camera is located at the top of the furnace. It observes the fuel bed temperature in the different zones of the stoker grate (Fig. 2). An image processor converts the camera's video pictures into signals that are integrated into the combustion control system as control variables.

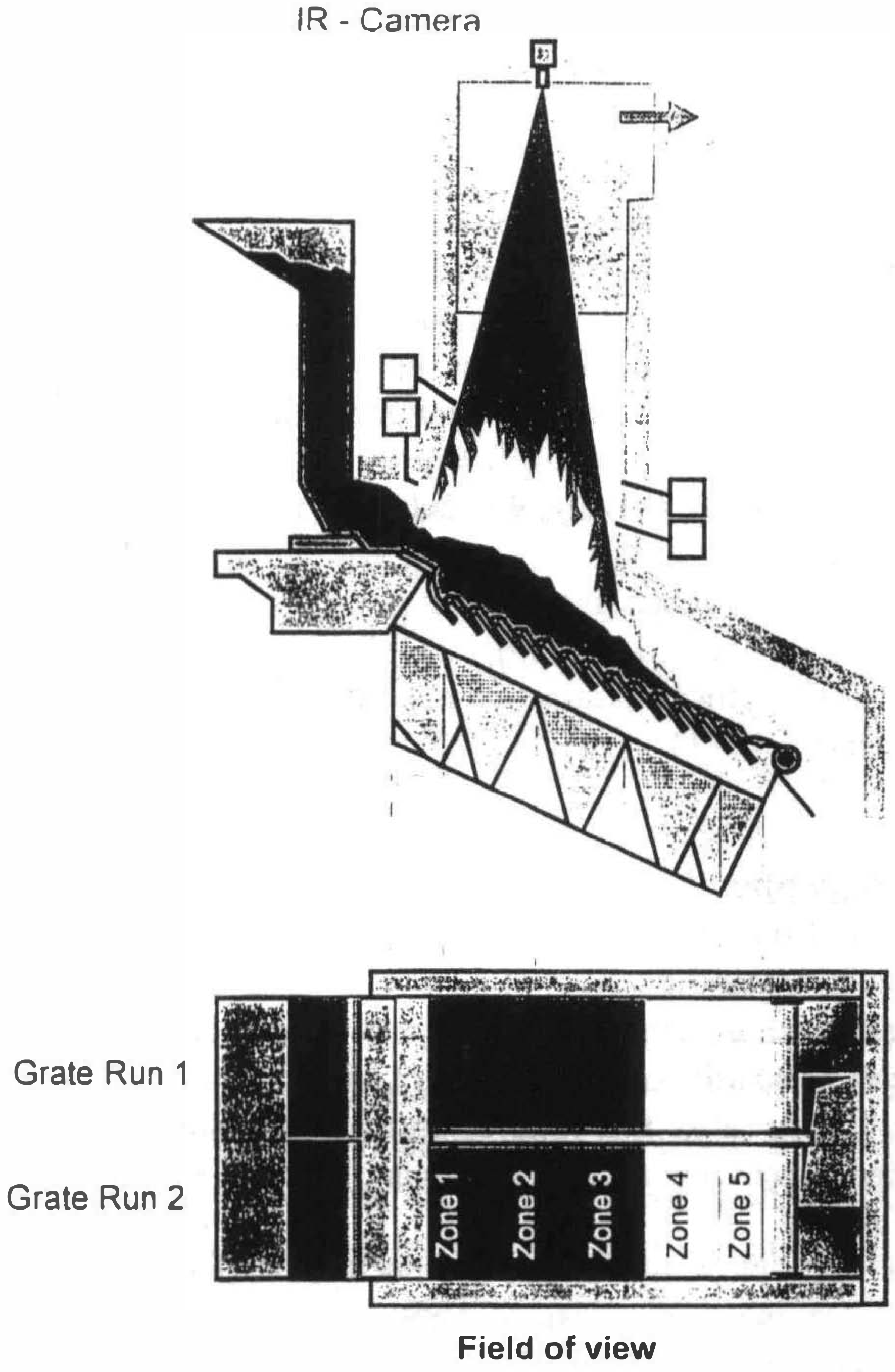


FIG. 2 FIELD OF VISION OF IR - CAMERA

Fuzzy logic combustion control design

A striking feature of fuzzy logic is the fact, that it can not only process control signals which are sometimes ambiguous, but also signals which might appear contradictionary. Control systems based on fuzzy logic determine the most plausible solution, stabilizing the control behavior. The response no longer fluctuates in amplitudes around a set point, but approaches it asymptotically. A fuzzy logic based control system therefore operates very stable.

TESTING IN COBURG, GERMANY

During the months of June and July, 1992 all the elements of the Syncom process were extensively tested in the waste-to-energy facility in the German city of Coburg. The following advantages over a conventional stoker fired massburn system were demonstrated:

- Intensified and evenly distributed, homogenized primary combustion on the grate
- Reduction of the combustion process related emissions (NO_x, CO, VOC)
- Improved bottom ash quality and reduced fly ash quantity
- Flue gas volume reduced by 40%-50%

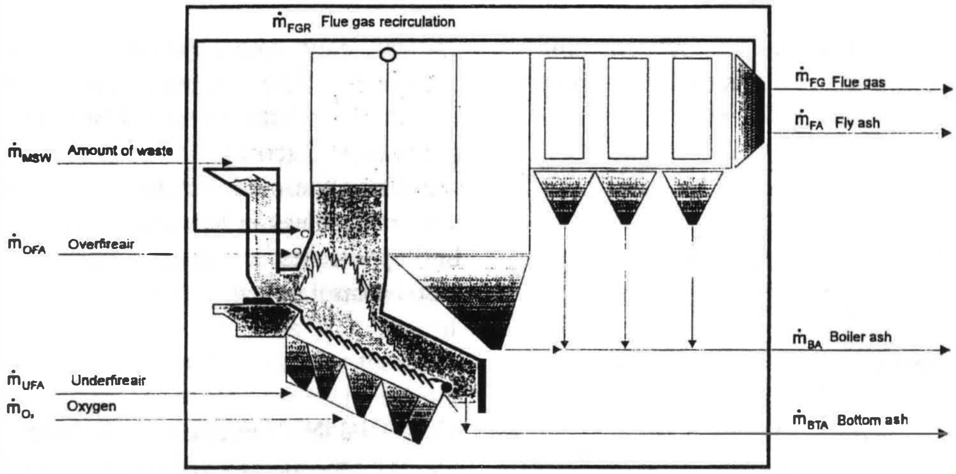
SUMMARY OF TEST RESULTS AND THEIR APPLICATION

The following is a summary of the test results and the application of the numbers for a specific project/proposal that was presented to the city of Boeblingen, Germany in May 1995.

The mass- and energy balances are related to the proposal, but the ash and air emission data is as tested in Coburg.

Mass balance

The mass balance compares conventional combustion with Syncom. The numbers are based on 1000 kg/h (2205 lb/hr) waste throughput (Fig. 3). It becomes evident, that the sum of the mass flows is approximately 40% smaller for the Syncom process. This is mainly related to the difference in flue gas quantity. It allows to reduce the size of the boiler by 20 to 25% and the air pollution control system after the extraction for FGR by approximately 40% for those parts that are sized proportional to the flue gas flow, like scrubber vessels, ducts, heaters, SCR, etc.



Flows	Input					Output				
kg/h	m_{MSW}	m_{OFA}	m_{UFA}	m_{O2}	Σ	m_{FG}	m_{FA}	m_{BA}	m_{BTA}	Σ
conv. firing	1000	2280	5310	-	8590	8370	7	13	200	8590
SYNCOM ®	1000	370	3650	310	5330	5110	5	11	204	5330

FIG. 3 SYNCOM MASS BALANCE

Energy balance

A simplified energy balance for a model facility was developed to better illustrate the different uses of energy within the overall process and the net energy available (Fig. 4).

The basic design data for the model facility is as follows:

• Throughput	150,000 T/a
• Hourly througput	2 x 10 T/h
• Availability	85 %
• Refuse lower heating value	11 MJ/kg (6111 Btu/lb)
• Total heat input	2 x 110 GJ/h
• Steam pressure	40 bar (580 psi)
• Steam temperature	400° C (752° F)
• Feedwater temperature	140° C (284° F)
• Flue gas temp. @ boiler exit	200° C (392° F)
• Flue gas temp. @ stack exit	150° C (302° F)
• Ambient temperature	10° C (50° F)

The physical layout includes:

- Combustion train with stoker, furnace, boiler and electrostatic precipitator
- PSA oxygen generation system
- Air pollution control system incl. 2-stage wet scrubber, SCR catalytic converter with reheat, heavy metal adsorption reactor with activated carbon, ID-fan and stack
- Waste water treatment facility with evaporator to produce reusable salts and gypsum
- Thermal cycle with turbine/generator, district heating exchangers and condensers, feedwater and steam system
- Electrical and I&C system and balance of plant

Energy inputs are from solid waste and natural gas needed for the SCR reheat. Energy outputs consist of stack losses, losses in the flue gas and waste water treatment systems and electrical and/or district heat energy.

Using the numbers of Fig. 4 to calculate the total plant efficiency we arrive at:

- case with district heat maximized:
  efficiency = (36+3.5) / (1.1+61.1) = 0.635
- case with electricity production maximized:
  efficiency = (0+11.7) / (1.1+61.1) = 0.188

Air Emissions

In Table 1 the air emission concentrations that are expected based on the testing of the Syncom process are presented in comparison to the German air emission standards for incinerators (17.BlmSchV). Table 1 lists also the total emissions that are produced by conventional combustion and Syncom in g/T of refuse.

It becomes clear, that due to the much lower flue gas volume, the total emission of pollutants is also substantially reduced. Another benefit is a reduction of NO_x in the flue gas before the SCR caused by the positive influence of the flue gas recirculation on NOx generation in the combustion chamber.

TAB. 1 COMPARISON OF EMISSION CONCENTRATIONS AND BURDENS

	Emission concentration in the flue gas			Emission burden per ton waste		
Pollutants		Limit value	Operation value		Normal	SYNCOM ®
Gas volume				m^3/h	5760	3200
Particulates	mg/Nm^3	10	< 1	g/h	< 5,8	< 3,2
CO	mg/Nm^3	50	15	g/h	86	48
THC	mg/Nm^3	10	< 4	g/h	< 5,8	< 3,2
NOx	mg/Nm^3	200	60	g/h	346	192
SO_2	mg/Nm^3	50	< 5	g/h	< 29	< 16
HCl	mg/Nm^3	10	< 1	g/h	< 5,8	< 3,2
HF	mg/Nm^3	1	< 0,1	g/h	< 0,6	< 0,3
Hg	mg/Nm^3	0,05	0,005	g/h	0,03	0,016
Cd, Ti	mg/Nm^3	0,05	< 0,005	g/h	< 0,03	< 0,016
Sb ... Sn	mg/Nm^3	0,5	< 0,2	g/h	< 1,15	< 0,6
PCDD/-F	mg/Nm^3	0,1	< 0,05	µg/h	< 0,3	< 0,16

Ash quality

The increased temperature of the fuel bed on the stoker causes a partial sintering of the bottom ash. This improves the burn-out and the destruction of organics. While the non volatile heavy metal compounds are fused and bound to the bottom ash, the volatile compounds escape in gaseous form and are collected with the boiler fly ash or the wet scrubber residues (Fig. 5). This shift in final location of collection of the volatiles causes an improvement of the bottom ash quality. It needs to be noted, that in Germany fly ash and bottom ash is not combined as part of the ash removal process, but is treated separately. Fly ash and/or scrubber residues which contain high concentrations of toxic substances (mainly heavy metals) are deposited in locations especially designed for this purpose, i.e. abandonded salt mines. The bottom ash easily meets the requirements of the German guidelines for disposal of residential waste (TASi) and disposal of residues from incinerators for residential waste (LAGA). As table 2 shows, in most cases the ash contains remarkably less regulated substances if the Syncom process is used versus conventional combustion techniques. The numbers in table 2 are based on actual testing in the Coburg facility. Since ash tests vary by nature and the tests are obviously done at different times, some of the differences can be attributed to variations in ash composition in general.

Economics

For the above mentioned project in Germany, a net tipping fee of 340 DM/T (approx. 220 $/sht) could be offered. While this appears extremely high for the US market, it needs to be understood, that the proposed facility is relatively small and has still very extensive air pollution control equipment included. The air pollution control equipment includes electrostatic precipitator, 2-stage wet scrubber with gypsum and salt recovery by evaporation, SCR with steam coil gas heater and gas/gas heat exchanger, sorbens reactor (i.e. Sorbalit) and all the chemical preparation facilities and other ancilliaries. This tipping fee assumes power consumption for the complete facility including the oxygen generation plant. Electric power is sold at 99 DM/MWh (approx. 7 ct/kWh). No district heat revenues are assumed.

In comparison, tipping fees for competing mas-burn and alternate technologies ranged up to 470 DM/T (approx. 305 $/sht).

TAB. 2 COMPARISON OF BOTTOM ASH QUALITY UNDER DIFFERENT OPERATION CONDITIONS

Tests at WTE Plant in Coburg		TASi Class 1 1)	LAGA 2)	Oxygen Enrichment	Camera Guided Combustion	Normal Operation
1. Strength						
Axial deformation	%	< 20	–	n.g.	n.g.	3
UCS	kN/m²	> 50	–	n.g.	n.g.	110
2. Organic Portion						
Ignition loss	WT-%	< 3	< 3	1.9	1.6	2.17
TOC	WT-%	< 1	–	0.93	0.95	1.63
AOC	WT-%	–	–	n.g.	0.83	0.89
TC	WT-%	–	–	n.g.	0.96	1.06
EC	WT-%	–	–	n.g.	0.12	0.17
3. Leachate						
ph Value *		5.5 - 13	7 - 13	11.5	12	12
Conductivity *	uS/cm	< 10000	< 6000	1350	2770	2830
TOC/DOC	mg/l	< 20	to be indicated	8.2	13.5	14.5
Phenols	mg/l	< 0.2	–	0.024	0.028	0.023
Arsenic	mg/l	< 0.2	to be indicated	n.g.	< 0.1	< 0.1
Lead	mg/l	< 0.2	< 0.05	< 0.001	< 0.1	0.09
Cadmium	mg/l	< 0.05	< 0.005	< 0.0001	< 0.01	0.011
Chromium-VI		< 0.05	–	n.g.	< 0.0005	< 0.0005
Chromium, total	mg/l	–	< 0.2	0.032	< 0.05	< 0.05
Copper	mg/l	< 1	< 0.3	0.08	0.2	0.23
Nickel	mg/l	< 0.2	< 0.04	< 0.001	< 0.1	< 0.1
Mercury	mg/l	< 0.005	< 0.001	< 0.001	< 0.0005	< 0.1
Zinc	mg/l	< 2	< 0.3	< 0.05	< 0.05	0.13
Fluoride	mg/l	< 5	–	0.023	0.23	0.228
Ammonium-N	mg/l	< 4	–	0.77	0.38	0.49
Chloride	mg/l	–	< 260	141	282	292
Cyanide, light fraction	mg/l	< 0.1	< 0.02	n.g.	< 0.005	< 0.005
Sulfate	mg/l	–	< 600	< 120	705	193
Nitrate	mg/l	–	–	< 0.1	n.g.	n.g.
AOX	mg/l	< 0.3	–	n.g.	< 0.01	< 0.01
Water soluble portion	Wt-%	< 3	–	0.84	1.64	1.21
PCDD/F (Nato-CCMS)	ng TE/kg	–	–	< 0.0017	< 0.004	< 0.0058
4. Composition						
Chloride	mg/kg TS	–	–	2765	4300	7303
Fluoride	mg/kg TS	–	–	94	30	26
Sulfate	mg/kg TS	–	–	15858	26650	17513
Water Content	%	–	to be indicated	15	14	15
Arsenic	mg/kg TS	–	to be indicated	n.g.	< 10	< 10
Lead	mg/kg TS	–	< 6000	475	826	559
Cadmium	mg/kg TS	–	< 20	5.4	< 5.8	5.5
Copper	mg/kg TS	–	< 7000	2933	1912	1068
Nickel	mg/kg TS	–	< 600	n.g.	838	494
Zinc	mg/kg TS	–	< 10000	2075	3944	2235
Mercury	mg/kg TS	–	to be indicated	< 0.06	< 0.05	< 0.02
Chromium, total	mg/kg TS	–	< 2000	n.g.	222	166
PCDD/F (Nato-CCMS)	ng TE/kg	–	0.6 - 30	16.5	17	23

The extractability of lipophilc substances has not been tested.

n.g: Not measured
*: Reference value
>: The value is beyond the analytical limit of detection
1): German Technical Instruction for recycling, Testing and other Forms of Municipal Waste Disposal (TASi)
2): Information sheet published by the German Länder Working Group Waste (Länder-Arbeitsgemeinschaft-Abfall = LAGA): Disposal or residues from incineration plants for municipal waste
UCS: Unconfined compression strength
to be indicated means: Measuring and reporting required; no regulatory limit exists

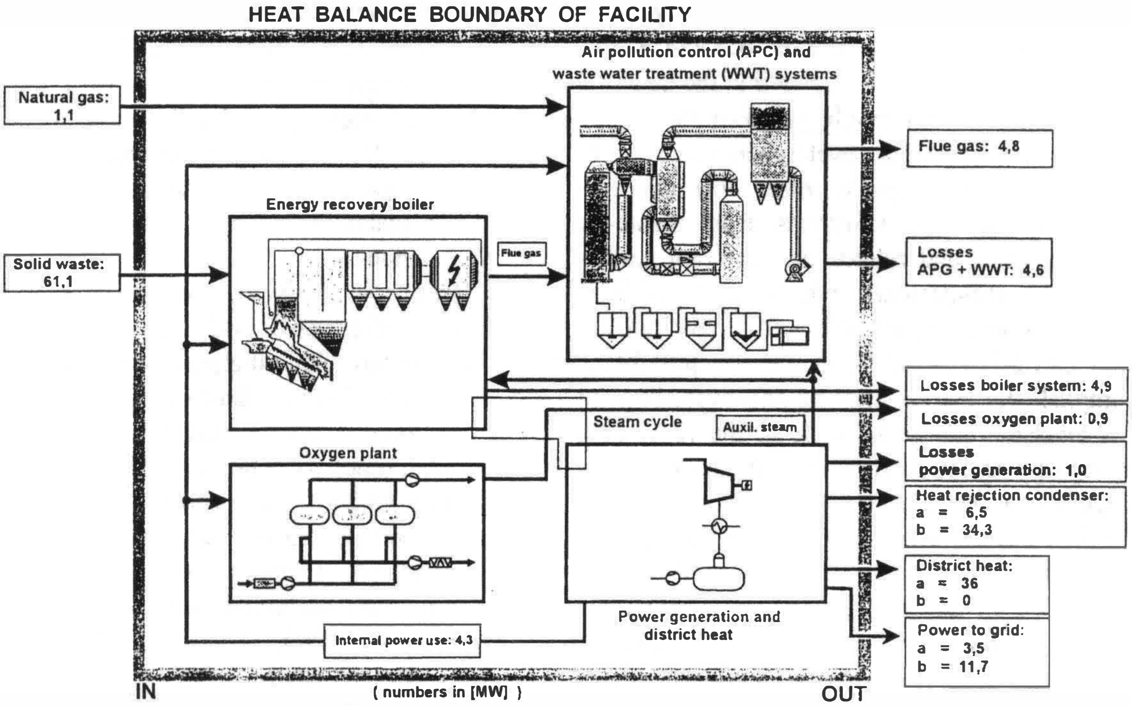


FIG. 4 ENERGY BALANCE OF SYNCOM ® - PROCESS
(BASE ON HEAT VALUE 11 MJ/kg)

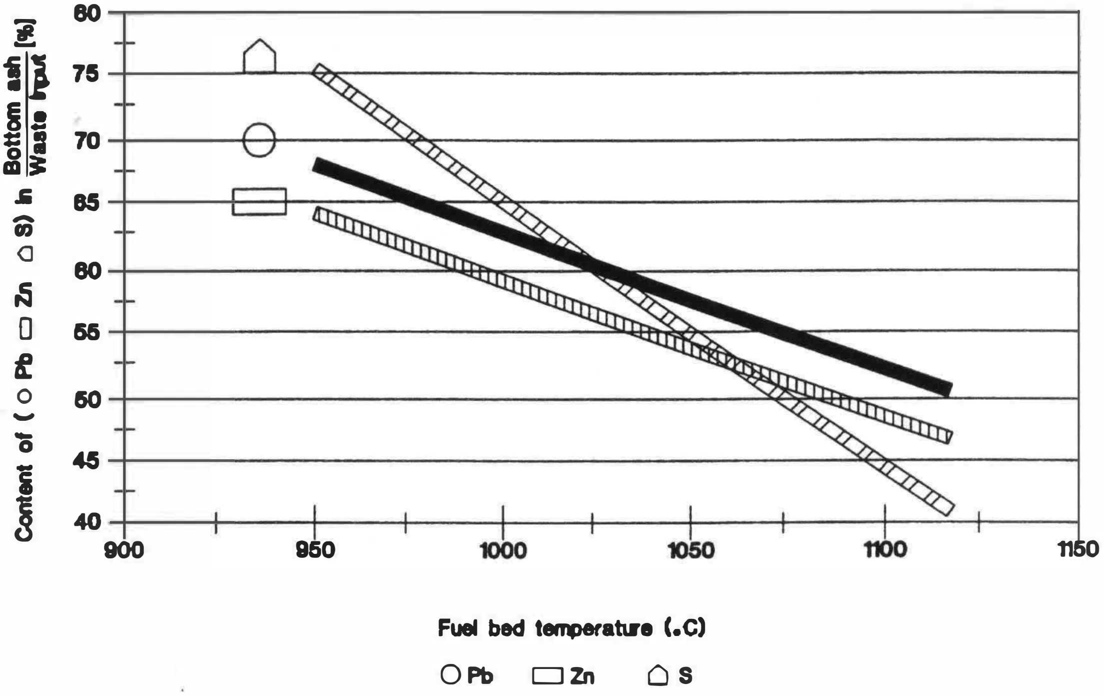


FIG. 5 CONTENT OF VOLATILES IN BOTTOM ASH
AT DIFFERENT FUEL BED TEMPERATURES

CONCLUSIONS

From the foregoing it can be concluded, that Syncom is a significant step forward in the quest for improved and environmentally sound combustion of municipal solid waste. The development was spurned by the need in Europe to meet ever stringent regulations regarding emissions from waste-to-energy facilities and related air pollution control equipment arrangements which lead to ever increasing waste disposal costs that have reached hereto unheard of proportions. It is now possible to accomplish the feat of meeting and exceeding the latest emission standards while at the same time keeping tipping fees and energy efficiencies at for Europe acceptable levels.

At this time the Syncom process can not pay for itself in typical US plants with scrubber/baghouse APC systems including SNCR and activated carbon injection based mercury control. A reduction in size of these systems would not create enough savings to justify the high costs for the Syncom system and its operation. However it shows, that new technologies based on the well proven reciprocating stoker fired combustion principles can further advance the state-of-the-art of waste-to-energy facilities without having to resort to "exotic" concepts if and when the situation warrants.

REFERENCES

Martin, J., and Behnke, S., 1994, "Das Syncom Verfahren-Umweltentlastung durch Muellverbrennung mit Rostfeuerung," (The Syncom Process - Relieving the environment through stoker fired refuse incineration) technical paper presented at "Kreislauf-Wirtschaft" (Recycling Economy) Symposium.

Behnke,S., Busch,M., and Knoerr,A., 1995, "Das Emissionsverhalten und der Wirkungsgrad einer thermischen Abfallbehandlungsanlage mit dem Syncom-Verfahren," (Emission levels and efficiency of a thermal waste treatment facility using the Syncom process) technical paper presented at VDI-Seminar 43-20-01, Duesseldorf "Energienutzung bei der thermischen Behandlung und Einschmelzung von Reststoffen" (Energy recovery from thermal treatment and melting of residual wastes).

Knoerr,A., 1995, "Thermische Abfallbehandlung mit dem Syncom-Verfahren," (Thermal waste treatment with the Syncom process) technical paper presented at Fachtagung 419513, Veitshoechheim "Thermische Abfallentsorgung" (Thermal waste treatment).