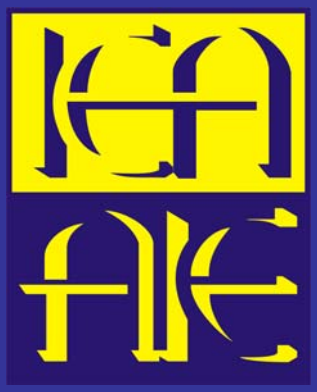
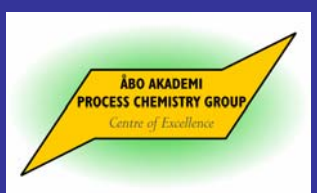


International Energy Agency

Fluidised Bed Conversion

Year report 2003



Åbo Akademi University,
Turku, Finland
Mikko Hupa
Maria Zevenhoven (ed.)

TABLE OF CONTENTS

INTRODUCTION

The International Energy Agency (IEA) Implementing Agreement for Cooperation in the Field of Fluidized Bed Conversion (FBC) of Fuels Applied to Clean Energy Production provides a framework for international collaboration on energy technology development and deployment. Currently 11 countries are active Contracting Parties: Austria, Canada, France, Finland, Greece, Italy, Japan, Korea, Portugal, Spain, Sweden and United Kingdom.

Fluidized beds offer several advantages over pulverised fuel combustion, notably low NOx emission, in-process capture of SO2 and the ability to burn a wide range of low-grade and potentially difficult fuels (including waste and biomass), as well as mixed fuels. The "conversion" (combustion or gasification) of solid fuels for production of heat and/or electricity can be made by various fluidised bed techniques working at atmospheric pressure or under pressure, usually: "bubbling" and "circulating" fluidized beds. Supercritical steam conditions can be used for fluidised bed boilers (atmospheric and pressurised) and efficiencies in the range of 45 per cent may be attained in the near future.

In addition, the technology can be employed for incineration and existing units have been successfully used for the disposal of high level PCB contaminated wastes, oil remediation and the elimination of low calorific wastes. The technology is also used in the metallurgical industry among others.

The Implementing Agreement on Fluidised Bed Conversion aims to bring together experts wishing to work on common problems. The main activity is technical exchanges during meetings and workshops. Participants are carrying out research on operational issues in support of local commercial fluidised bed conversion activities and sharing the results. Mathematical modelling has been a major activity in the past and a "1D" model for atmospheric fluidised bed combustion of coal has been developed and the exchanges in "3D" modelling of gas/solid flows as been very fruitful in permitting the development of knowledge of local solid concentration and heat transfer.

In addition, efforts are undertaken in the field of:

- solids attrition and fragmentation
- NOx and N2O formation and reduction
- sorbent reactivity and sulphur capture mechanisms
- bed sintering/agglomeration problems
- ash utilisation.

The Agreement has published a series of compilation of outstanding papers on R&D activities in fluidised bed conversion and a guide book for the use of the "1D" CFB combustion model.

MEMBERCOUNTRIES

Member countries	Contracting parties	Contact person
Austria:	University of Vienna	Franz. WINTER
Canada	CETC-NRC	E.J. (Ben) ANTHONY
Finland	Åbo Akademi University	Mikko HUPA
France	ÉDF-DER	Philippe JAUD
Greece	VAL GROUP	Emanuel KAKARAS
Italy	ÉNEL	Sauro PASINI
Japan	NEDO	Hiroshi AIDA
Korea	KEPCO	Jong-Jin KIM
Portugal	INETI	Ibrahim GULYURTLU
Spain	CIEMAT	Andrés CABANILLAS
Sweden	NUTEK	Bo LECKNER
UK	Imperial college	Rafael KANDIYOTI

OPERATING AGENT:

Åbo Akademi University, Mikko Hupa (from May 2002 onwards)
Maria Zevenhoven (coordinating assistant)

EVENTS

46th IEA-FBC meeting held in conjunction with the 17th International FBC conference. A workshop on "Co-combustion in FBC". 8 presentations were held before an audience of 19 people.

47th IEA-FBC meeting held on October 13-14th, in Zlotniki.
A Workshop on "large scale FBC" an technical session were held. The Turov power plant was visited as well. 33 partcipants were present and listened to 12presentations

COUNTRY REPORTS

AUSTRIA

News

A new fluidized bed combustor for co-combustion of sewage sludge (approx. 90.000 t/a) and municipal solid waste (approx. 90.000 t/a) has been started up successfully at EBS/Vienna. A rotating fluidized bed system (RFBC) was chosen for this purpose.

Commercial Installations

owner/ location	year	type	capacity	fuels
Leykam/ Gratkorn	1981	BFBC	14 MW	Bark, sludge
Hamburger/ Pitten	1984	BFBC	65 MW	Coal
Leykam/ Bruck	1984	BFBC	15 MW	Bark, coal, sludge
Patria/ Frantschach	1984	CFBC	61 MW	Bark, coal, sludge
Leykam/ Gratkorn	1986	CFBC	133 MW	Bark, coal, sludge
Lenzing/ Lenzing	1987	CFBC	108 MW	Bark, coal, sludge
Lenzing/ Lenzing	1998	CFBC	110 MW	Plastics, waste, sludge
Solvay/ Ebensee	1987	CFBC	43 MW	Coal, wood waste
Steyrerm. Papier/ Steyrermühl	1994	CFBC	50 MW	Bark, wood
Funder/ St.Veit	1990	FICFBC	33 MW	Bark, sludge, sawdust, wooden residue
EBS/Vienna	1992	FBC	3 x 25 MW	Sewage sludge
EBS/Vienna	2003	RFBC	40 MW	Municipal Solid waste, sewage sludge
Verbund/Zeltweg*)	1998	CFBG	10 MW	Wood
Güssing	2001	DFBG	8 MW	Wood chips, wood residues

BFBC bubbling fluidized bed combustor
CFBC circulating fluidized bed combustor
FICFBC fast internal circulating fluidized bed combustor
CFBG circulating fluidized bed gasifier

DFBG dual fluidized bed gasifier
RFBC rotating fluidized bed combustor
*) not in operation
The table contains the most important features of fluidized bed combustors and gasifiers currently in operation.

Research centers

In Austria research on fluidized bed combustion and gasification is carried out mainly at the Vienna and Graz University of Technology:

1. Institute of Chemical Engineering, Getreidemarkt 9/166, A1060 Vienna
2. Institute of Thermal Engineering, Getreidemarkt 9/302, A1060 Vienna
3. Institut für Apparatebau, Mechanische Verfahrenstechnik und Feuerungstechnik, Infeldgasse 25/B/I, A-8010 Graz

Companies

1. AE Energietechnik
2. Verbundgesellschaft
3. Repotec

CANADA

FBC and Gasification Research at CETC

Fluidized bed combustion and gasification research carried out at CETC laboratories in 2003 has been directed to the areas of: sorbent reactivation, agglomeration, hydration and carbonation of FBC ashes, and emissions reduction from FBC burning high-volatile fuels or methane. Active collaborations were carried out between CETC and several institutions including: the University of Toronto, the Technical University of Vienna, Cracow University of Technology, the University of Naples (Frederico II), Kyoto University and the Instituto de Carboquimica in Spain. This work has led to a series of journal and conference publications that are listed below. In addition, CETC has carried out a number of studies for companies and government institutions, including:

1. Studies related to the Zero Emissions Coal Alliance (ZECA) process, including a study on magnesium silicate carbonation, for Environment Canada; a feasibility study on the shift reactor for the ZECA concept; and an ASPEN modelling study of the process.

2. Application of IGCC Technology in Canada--Phase V, for Environment Canada. This work included a comprehensive analysis of the ZECA process, an update of worldwide gasification activity, and a site visit report for the Pi**Z**on Pine fluidized bed coal gasifier near Reno, Nevada.

3. Studies on reactivation, including fundamental studies of the hydration process, and a series of three papers on a new patented concept for sorbent reactivation for firing high-sulphur coals.

4. Gas Burning in FBC Systems, an internal study. This on-going project examined the possibility of co-firing natural gas in a FBC to enhance performance in terms of carbonaceous emissions reduction. A successful conclusion would allow CETC to gain the necessary experience to further examine flare gas combustion (for a flaring consortium) and hydrogen combustion (for ZECA).

5. FBC combustion of residues from the Sydney Tar Ponds. This project is in response to a request for proposals from the Nova Scotia Government, and represents one of a limited number of projects selected for funding. The most successful approach will be chosen for final reclamation of the Sydney Tar Ponds site.

6. Case studies on biomass/municipal solid waste-fired fluidized bed gasifiers, as part of work for IEA Bioenergy Task 36--Energy from Integrated Solid Waste Management Systems.

Journal Publications

1. Wang, J. and Anthony, E.J., "A Study of Thermal-Cracking Behavior of Asphaltenes", Chemical Engineering Science, 58, 157-162, 2003.
2. Wang, J., Jia, L. and Anthony, E.J., "Mechanism for N_2O Formation from NO at Ambient Temperature", AIChE, 49, 277-282, 2003.
3. Anthony, E.J., Jia, L., Charland, J.-P., and Laursen, K., "Agglomeration Behaviour of Dolomitic Sorbents during Long-Term Sulfation", Energy and Fuels, 17, 348-353, 2003.
4. Anthony, E.J., Jia, L. and Qiu, K., "CaS Oxidation by Reaction with CO_2 and H_2O", Energy and Fuels, 17, 363-368, 2003.

5. Anthony, E.J., MacKenzie, A.J., Trass, O., Gandolfi, E., Iribarne, A.P., Iribarne, J.V., and Burwell, S.M., "Advanced Fluidized Bed Combustion Sorbent Reactivation Technology", Industrial and Engineering Chemistry Research, 42, 1162-1173, 2003.
6. Abanades, C.J., Anthony, E.J., Garcia-Labiano, F., and Jia, L., "Progress of Sulfation in Highly Sulfated Particles of Lime", Industrial and Engineering Chemistry Research, 42, 1840-1844, 2003.
7. Jia, L, Wang, J. and Anthony, E.J., "Reactivation of Fluidized Bed Combustor Ash for Sulphur Capture", Chemical Engineering Journal, 94, 147-154, 2003.
8. Jia, L, Anthony, E.J. and Laursen, K., "The Effect of $CaSO_4$ on the Strength Development of Sorbents in CFBC Boilers Firing High-Sulphur Fuels", Industrial and Engineering Chemistry Research, 42, 3245-3249, 2003.
9. Iribarne, J.V., Anthony, E.J., and Iribarne, A.P., "A Scanning Electron Microscope Study on Agglomeration in Petroleum Coke Fired FBC Boilers", Fuel Processing Technology, 82, 27-50, 2003.
10. Anthony, E.J., Berry, E.E., Blondin, J., Bulewicz, E.M. and Burwell, S.M., "Advanced Ash Management Technology for CFBC Ash", Waste Management Journal, 23, 503-516, 2003.
11. Anthony, E.J. McCleave, R., Gandolfi, E, and Wang, J., "Industrial-scale Demonstration of a New Sorbent Reactivation Technology for Fluidized Bed Combustors", Journal of Environment Management, 69. 177-185, 2003.
12. Wu, Y, Anthony, E.J., and Jia, L., "Hydration of Partially Sulphated Limestone", Canadian Journal of Chemical Engineering, accepted 2003.
13. Salvador, C., Lu, D., Anthony, E.J., and Abanades, J.C., "Enhancement of CaO for CO_2 Capture in a FBC Environment", Chemical Engineering Journal accepted 2003.

Conference Papers

1. Anthony, E.J., Jia, L, Wu, Y. and Caris, M., "CFBC Hydration Studies", Fourth International Symposium of the South-East Europeann Countries (SEEC), Fluidized Beds in Energy Production, Chemical, Processing Engineering and Ecology, p. 167-173, Thessaloniki, Greece, April 3-4th, 2003.
2. Wu, Y., Anthony, E.J., and Jia, L., "Hydration of Partially Sulphated CFBC Ash with Saturated Steam", 17th International Conference on FBC, Jacksonville, FA, May 2003.
3. Jia, L, and Anthony, E.J., "Agglomeration in an Industrial FBC Boiler", Jia, L, and Anthony, E.J., 17th International Conference on FBC, Jacksonville FA, May 2003.
4. Bulewicz, E.M., Gora, D., and Anthony, E.J., "The Behaviour of Free Lime in CFBC Ashes, 17th International Conference on FBC, Jacksonville, FA, May 2003.
5. Lu, D. and Anthony, E.J., "Combustion Characteristics of Natural Gas in a Circulating Fluidized Bed", 17th International Conference on FBC, Jacksonville, FA, May 2003.
6. Montagnaro, F., Salatino, P., Scala, F., Wu, Y., Anthony, E.J., and Jia, L., "Assessment of Sorbent Reactivation by Water Hydration for Fluidized Bed Combustion Applications", 17th International Conference on FBC, Jacksonville, FA, May, 2003.
7. Abanades, C.J., Anthony, E.J., Alvarez, D. and Lu, D., "In-Situ Capture of CO_2 in a Fluidized Bed Combustor", 17th International Conference on FBC, Jacksonville, FA, May 2003.
8. Wang, J., Anthony, E.J., and Abanades, C.J., "A Simulation Study for Fluidized Bed Combustion of Petroleum Coke with CO2 Capture", 17th International Conference on FBC, Jacksonville, FA, May 2003.
9. Anthony, E.J., Jia, L. and Burwell, S.M., "Petroleum Coke FBC Ash – A Detailed Look at the Calcium in the Ash", 17th International Conference on FBC, Jacksonville, FA, May 2003.
10. Wang, J., and Anthony, E.J., A Discussion of the Temperature Maximum for Sulfur Capture Efficiency in Fluidized Bed Combustion Systems", 17th International Conference on FBC", Jacksonville, FA, May 2003.

11. Jia, L. and Anthony, E.J., "Mineral Carbonation with Magnesium Silicates", Proceedings of the Third Mediterranean Combustion Symposium, Marrakech, Morocco, pp. 259-270, 2003.
12. Preto, F., Wang, J., Jia, L., and Anthony, E.J., "A Study on Mechanisms of N_2O Formation in Post Combustion Gas", Proceedings of the Third Mediterranean Combustion Symposium, Marrakech, Morocco, pp. 665-676, 2003.

Books Edited

Technical editor: E.J. Anthony, of "Fluidized Bed Combustion", by Simeon N. Oka, published Marcel Dekker, 2003, ISBN: 0-8247-4699-6.

FINLAND

Overview

Fluidized bed conversion has continued to play an important role in the Finnish energy economy. Most of the boilers were bubbling beds, but one, the Ahlholmens Kraft boiler in Pietersaari is a circulating fluidized bed boiler. The boilers burn a great variety of fuels and the role of biomass and waste derived fuels is remarkable.

The largest boiler is the Ahlholmens Kraft CFBC with a thermal power of 550MW. This is the world's largest FBC for biomass fuels. In 2003 the main fuels burned here were mixtures of coal, peat and bark. Table 1 summarizes these new boilers. It shows also a list of large new boilers started up in 2002.

Research

The research activities in the FBC related topics have also been active. Most of the research work is associated with the ongoing national research programs: JÄTE, KESTO, CLIMTECH, initiated and coordinated by the National Technology Development Agency, TEKES. The program JÄTE focuses on the use of various types of waste in the energy conversion and contains several projects with connection to FBC technology. The KESTO program focuses on material issues in energy technology. In the KESTO program some work is done on the problem of super heater corrosion in the modern high steam data FBC units fired with biomass. CLIMTECH focused on climate change and technology. Also projects have been financed within the 6th framework of the specific research and technological program" Energy, environment and sustainable development" of the European Union.

Research centers

Helsinki University of Technology
Tampere University of Technology
Oulu University
Lappenranta University of Technology
Åbo Akademi University

Largest companies

Foster Wheeler Oy, Kvaerner Pulping Oy

Table 1: Recent large fluidized bed installations in Finland

A. Bubbling fluidized beds by Foster Wheeler

Delivery year	Costumer/site	Capacity MWt	Steam data			Fuels	Remarks
			Flow kg/s	Press. bar	Temp. °C		
2002	Äänevoima OY Äänekoski Finland	157	60,2	105	535	Bark, wood residue, sludge, peat oil	EPC Co-generation powerplant 37 MWe
2002	Jämsenkosken Voima Oy Jämsenkoski Finland	185	70	107	535	Peat, bark, chips, sludge oil	

A2. Circulating fluidized beds by Foster Wheeler

2003	AS Narva Elektrijaamad Narva Estonia	243	90	131	540	oilshale	
2003	AS Narva Elektrijaamad Narva Estonia	243	90	131	540	oilshale	

B. Bubbling fluidized beds by Kvaerner Pulping

Delivery year	Costumer/site	Capacity MWt	Steam data			Fuels	Remarks
			Flow kg/s	Press. bar	Temp. °C		
2002	Järvi-Suomen Voima OY Ristiina Finland	74	30	84	482	bark, plywood residue, grinding dust, peat, forest residue, oil	
2002	Kymin Voima OY Kuusankoski Finland	269	107	114	541	Bark forest residue, sludge peat. gas oil	
2003	Kotkan Energia Oy Kotka Finalnd	67	211	62	480	peat, wood chips, forest residue	
2003	Järvi-Suomen Voima Oy Savonlinna Finalnd	72	28	90	523	birch bark, plywood, peat, forest residue, fine sawdust	

Some publications (journal papers and conference)

(Source: Science direct, Proceedings of 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

1. Enestam S.; Fabritius M.; Hulkkpnen S.; Röppänen J.; **Control of ash related operational problems in BFB combustion of biofuels and waste**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

2. Hiltunen M; Vilokki H.;**Green energy from wood based fuels using foster wheeler CFB boilers**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

3. Hirsch, Martin; Stroeder, Michael; Schmidt, Hans-Werner; Guentner, Jochen; Missalla, Michael; Rahn, Martin; Schalk, Wolfram; Sneyd, Stuart; Stockhausen, Werner; Zingrebe, Horst. **Procedure for the production of anhydrous aluminum oxide from preheated aluminum hydroxide in a fluidized-bed reactor.**

4. Kettunen A.; Hyppänen T.; Kirkinen A-P; Maikkola E.; **Model based analysis of transient behavior of large scale CFB boilers**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

5. Kinnunen, P. **Aspects considered in new CFB boiler design for Narva power plants.** Oil Shale (2003), 20(3, Special), 371-374

6. Kokko A., Nickulll S., **The first operational experience of world's larges biofuel fired CFB**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

7. Kouvo Petri **Trace metal distribution and control in the pilot-scale bubbling fluidized bed combustor equipped with the pulse-jet fabric filter, limestone injection, and the humidification reactor**. Journal of the Air & Waste Management Association (1995) (2003 Apr), 53(4), 406-16.

8. Kouvo, Petri Erik. **Formation and control of trace metal emissions in co-firing of biomass, peat, and wastes in fluidised bed combustors.** (2003), 75 pp.

9. Kouvo, Petri; Backman, Rainer. **Estimation of trace element release and accumulation in the sand bed during bubbling fluidised bed co-combustion of biomass, peat, and refuse-derived fuels.** Fuel (2003), 82(7), 741-753.

10. Kurkela, E.; Palonen, J.; Kivelae, M.; Takala, H. **Solid recovered fuel gasification for Co-combustion in pulverised coal-fired boilers - lahti case study.** Pyrolysis and Gasification of Biomass and Waste, Proceedings of an Expert Meeting, Strasbourg, France, Sept. 30-Oct. 1, 2002 (2003), Meeting Date 2002, 571-584.

11. Lampenius, H. **The Foster Wheeler biomass gasification experience.** IMechE Conference Transactions (2003), (3, Renewable Bioenergy--Technologies, Risks, and Rewards), 99-111.

12. Lind Terttaliisa; Hokkinen Jouni; Jokiniemi Jorma K; Saarikoski Sanna; Hillamo Risto **Electrostatic precipitator collection efficiency and trace element emissions from co-combustion of biomass and recovered fuel in fluidized-bed combustion**. Environmental science & technology (2003 Jun 15), 37(12), 2842-6.

13. Lundqvist, R. G. **Designing large-scale circulating fluidized bed boilers.** VGB PowerTech (2003), 83(10), 41-47.

14. Mueller, Christian; Skrifvars, Bengt-Johan; Backman, Rainer; Hupa, Mikko. **Ash deposition prediction in biomass fired fluidised bed boilers - combination of CFD and advanced fuel analysis.** Progress in Computational Fluid Dynamics (2003),

15. Mueller C.; Lundmark D.; Skrifvars B-J.; Backman R.; Zevenhoven M.; Hupa M.; **CFB based ash deposit prediction in a BFB firing mixtures of peat and forest residue**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

16. Myöhänen K.; Hyppänen T.; Miettinen J.; Parkkonen R.; **Three dimensional modelling and model validation of circulating fluidized bed combustion,** 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

17. Nuutinen L.; Tiainen M.; Virtanen M.; Laitinen R.; **Coatings on bed particles from FB-combustion of different biomasses**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

18. Oikari, Risto; Aho, Martti; Hernberg, Rolf. **Demonstration of a New On-Line Analyzer for the Measurement of Vaporized Toxic Metal Compounds in a Fluidized Bed Combustor.** Energy & Fuels (2003), 17(1), 87-94.

19. Partanen, J.,:Backman P.,;Backman R.; Hupa M.;**Formation of calcium chloride and its interaction with the sand particles during fluidised bed combustion,** 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

20. Saeed L.; Tohka A.; Zevenhoven R.; **An experimental assessment of two stage fluidised bed combustion of high PVC solid waste with HCl recovery**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

21. Saastamoinen, J. J.; Tourunen, A.; Hamalainen, J.; Hyppanen, T.; Loschkin, M.; Kettunen, A. **Analytical solutions for steady and unsteady state particle size distributions in FBC and CFBC boilers for non-breaking char particles.** Combustion and Flame (2003), 132(3), 395-405.

22. Saastamoinen, J. J.; Tourunen, A.; Hamalainen, J.; Hyppanen, T.; Loschkin, M.; Kettunen, A. **Analytical solutions for steady and unsteady state particle size distributions in FBC and CFBC boilers for non-breaking char particles.** Combustion and Flame (2003), 132(3), 395-405.

23. Silvenoinen J.; **A new method to inhibit bed agglomeration problems in fluidized bed boilers**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

24. Skrifvars B-J; Yrjas P.; Hupa M; Aho M; Silvenoinen J.; Etelääho R.; Kouki J.; Saari K.;**Fireside deposit formation in biomass fired FBC: A comparison between tests performed in three significantly different sized combustors**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

25. Tossavainen V.; Karvinen R.;Ylitalo M.; **Modeling air jet penetration into gas particle suspension cross flow,** 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

26. Tourunen A.; Saastamoinen J. Hämäläinen J.; Paakkinen K; Hyppänen T.; Kettunen A.; **Study of operation of a pilot CFB reactor in dynamic conditions**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

27. Zevenhoven, M.; Skrifvars B-J.; Yrjas P.; Backman R.; Mueller C; Hupa M., **Cofiring in FBC A challenge for fuel characterization and modelling**, 17th International Fluidized Bed Combustion Conference, Jacksonville, USA (2003)

GREECE

CERTH/ISFTA – Research activities in fluidised bed conversion

Project Acronym: CLEFCO
Full Title: Advanced CFB for clean and efficient coal power

To fulfill the needs of development of the Once Through Supercritical (OTSC) Circulating Fluidized Bed (CFB) technology comprehensive understanding of CFB combustion processes must be achieved. This promotes boiler designers to meet the requirements of utility boilers to secure boiler performance and reliability at OTSC operation. In particular, more distinct understanding of combustion behaviour in OTSC CFB application during multifuel operation is needed to meet the additional requirements of the boiler control algorithms. The strategic importance and attractiveness of the OTSC CFB design is based on capability on multifuel operation that makes it possible to decrease CO_2 emissions remarkably compared to current designs down to level of 500 – 600 $kgCO_2$/ MWhel, depending on the degree of fuel substitution. The important aim of the proposed work is also to promote scale-up of the design of an OT CFB plant up to 600 MWe size.

Project Acronym: CARNOT
Full Title: Circulating fluidized bed for the clean and very efficient retrofit of an existing coal-fired power plant

The main objective of the project is to facilitate the commencement of a CCT project in a coal-fired power plant in Russia, which will act as a "precursor" of similar activities in the area. Namely, feasibility and an engineering study will be carried out aiming at the rehabilitation of a coal-fired power plant with the use of fluidized bed technology. The replication potential of this project will be examined both in Russia and accession countries, meeting in this way the demands for cleaner and more efficient solid fuels utilization.

Project Acronym: EPAN
Full Title: Investigation of the biomass combustion and gasification processes in fluidized beds.

The project addressed the simulation of the conversion processes in a fluidized bed boiler, operated in steady-state conditions with biomass fuels. In order to achieve this aim a mathematical modeling work was carried out. The mathematical model was developed to simulate the combustion/gasification of solid biomass particle. The mathematical model was then converted into a numerical code, having as main input parameters the particle properties, the chemical analyses of the biomass and the fluidized bed characteristics.

NTUA – Research activities in fluidised bed conversion

Project Acronym: NewPronox
Full Title: Impact of a new process for NO_x reduction on reliability, operating performance and toxicity in recirculating fluidised bed boilers.

Aim of this project is to develop a fine tuning micro combustion process on the control of oxygen content in the different levels of the riser in circulating fluidised bed. The validation of this method takes place in pilot scale and fundamental data are collected to evaluate the optimisation of this new process with regard to several operating parameters and the resulting gaseous emissions and ash related problems.

During the last year the main activities of NTUA-LSBTP were aiming to prepare the $100kW_{th}$ circulating fluidised bed facility for the experimental campaign, which has started in the beginning of November 2003 and is still in progress.

Project Acronym: Coal Optimisation
Full Title: Measures to improve availability and reduction in operating costs of coal and biomass burning power plants

Aim of the project is to analyse on-line large coal fired utility boiler conditions and use the measured results directly to control combustion and sootblowing systems, allowing an increase in efficiency and a reduction in operation costs; so, research activity is mainly addressed to a better understanding of the combustion behavior of the coals and their blends with biomass, with particular attention on fouling at the heat transfer banks.

During the last year NTUA-LSBTP's main activities were aiming to prepare the lab-scale fluidised bed facility for the experimental campaign, which will start in the beginning of 2004.

Project Acronym: MBM
Full Title: Co-combustion of meat and bone meal in coal power plants

The aim of the project is the investigation of meat and bone meal, as substitute fuel, in power plants with high quality results in combustion, emission and ash-valorisation. Laboratory scale tests will allow to get important information about MBM, investigating the risk of auto combustion, reactivity, combustion quality, gaseous emissions, the effect of MBM combustion on air pollutants, especially toxic dioxins and furans and analysing the produced flue gases. Full-scale tests in a PC power plant of SNET will provide industrial data, especially about gaseous emissions and ashes valorisation. Special attention will be drawn on the influence of the flue gases on the equipment downstream to the boiler, such as ECO, $DENO_X$ and $DESO_X$ and on. The collaboration between utilities and research institutes should provide reliable results as a basis for further strategic decisions for the treatment of MBM in the EU.

During the last year NTUA-LSBTP's main activities were aiming to prepare the lab-scale fluidised bed facility for the experimental campaign, which will start in the beginning of 2004.

ITALY

Commercial installations

Owner/ Location	Start-up	Type	Capacity	Fuel
ENEA Casaccia	-	***BFBC***	1,5 MWth	***RDF***
ACCAM Busto Arstizio	1999	***BFBC***	Pilot plant	***RDF***
FERRERO SpA Macomer	August 1994	***2 x FICFBC***	2 MW	***RDF***
AREA Ravenna	1999	***BFBC***	7 MW	***RDF***
Cartiere Burgo Mantova	1999	BFBC	3,2 MW	Paper sludge
ENI Scarlino	1999	BFBC	3 x 6 MW	RDF
Sicet Ospitale di Cadore	1999	CFBC	17,5 MW	Wood, Bark
Termomeccanica Lucca	1999	BFBC	2x12 MW	RDF
ENI Porto Marghera	2000	BFBC	2 x 14 MWth	Refused oil
Lomellina Energia Parona	2000	CFBC	15 MW	RDF
Cartiere Burgo Verzuolo	2001	BFBC	7 MW	Paper sludge
BAS Bergamo	2002	CFBC	10 MW	RDF
Appia Energy Massafra	2003	CFBC	10MW	RDF.
BiomasseItalia Strongoli	2003	CFBC	2 x 20 MW	biomass
Ecoenergia Corteolona	2003	**BFBC**	30 MWth	RDF
Euroenergy Cutro	2003	**BFBC**	14 MW	Wood chips
Termomeccanica Calabria	2003	**BFBC**	2x30MWth	RDF
ENEL Produzione Sulcis	2005	**CFBC**	340 MW	Coal
Kamine Colleferro	2003	**CFBC**	10 MWe	RDF
AGSM Verona	1992	**BFBC**	38 MWe	RDF
AGAC Reggio Emilia	1987	**FBC**	18.6 MWe	RDF (multifuel)

BFBC	bubbling fluidized bed combustor		CFBC circulating fluidized bed combustor
FICFBC	fast internal circulating fluidized bed combustor	CFBG	circulating fluidized bed gasifier

Note:
The table contains the most important features of fluidized bed combustors currently in operation in Italy or starting up in the next years.

Research centers

INSTITUTION OR COMPANY	OWNER	MAIN ACTIVITY	TYPE OF INTEREST IN FBC
CNR/Istituto Ricerche Combustione	Ministry of Education, University and Research	Research institute	Fundamental and applied research in fluidized bed combustion, gasification and pyrolysis
Seconda Università di Napoli Dipartimento di Scienze Ambientali	Ministry of Education, University and Research	Public University	- Fluidized bed processing of plastics for recycle - Fundamental and applied research on energy recovery from wastes
Università "Federico II" di Napoli Dipartimento di Ingegneria Chimica	Ministry of Education, University and Research	Public University	- Fundamental research on sorbent particle behavior - Fundamental and applied research on combustion, gasification and pyrolysis in FBC
Università dell'Aquila Dipartimento di Chimica, Ingegneria Chimica e Materiali	Ministry of Education, University and Research	Public University	- Fundamental research on fluid dynamics
Università di Salerno Dipartimento di Ingegneria Chimica ed Alimentare	Ministry of Education, University and Research	Public University	- Fundamental research in fluidized bed processing of food - Fundamental research of fluidized combustion of liquid fuels or liquid-like wastes
Università di Sassari Dipartimento di Chimica	Ministry of Education, University and Research	Public University	- Fundamental and applied research on pyrolysis and gasification of biomass
Università di Teramo Facoltà di Agraria	Ministry of Education, University and Research	Public University	- Fundamental and applied research on fluidized gasification of biomass

Companies

COMPANY	OWNER	FBC PRODUCTS
CCT	Gruppo Marcegaglia	• Industrial Boilers • Heat Recovery Steam Generators • Waste to Energy Boilers • Fluidized Bed Combustors (EPI license) • Gasification Systems

KOREA

News

The Korea Electric Power Corporation (KEPCO) contracted Memorandum of Agreement (MOA) for build, own and operation (BOO) of thermal power plants, CFB boilers, with the Ministry of Energy in Philippines last June 2003. The KEPCO according to this MOA has planned to make investment for 2-units CFB boilers (50,000 kWe x 2) at Panay in Philippines and to operate the boilers for 25 years ahead. On the other hand, Prior to this KEPCO had also contracted Memorandum of Understanding (MOU) for construction and operation business of CFB power plants (55,000 kWe x 2 units of CFB at Row-Yang, 50,000 kWe x 2units of CFB at Mu-Cheok) with a public electric power corporation at Ha-Nam Province in China January 2003.

The Korea Electric Power Research Institute (KEPRI) plans to start a new research project, a feasibility study on the conversion of the pulverized coal boiler using Korean anthracite into a CFB boiler' from April 2004. In this feasibility study, the economic and environmental effect of the boiler before and after conversion will be investigated in priority.

Activities

KIChE fall meeting was held on 24-25 October 2003 at Hanyang University in Seoul, Korea. In this meeting, there were 13 oral and 9 poster presentations relating with FBC technology, and they are as follows;

Title	Authors	Affiliation
Particle size distribution of Zinc Titanate in FBC reactor	Y.S.Moon,* J.H.Choi,* C.K.Lee, J,I,Son	*Kunkuk Univ., KIER
Experiment of CO_2 recovery in a fast fluidized bed reactor	C.K.Lee, S.H.Cho, S.W.Hong, Y.W.Ryu, K.T.Jin, K.H.Moon*	KIER, *Doosan Heavy Industry
Analysis of solid circulation model in a CO_2 absorption & recovery tower	*J.H.Choi, *J.Y.Park, **S,H.Cho, **C.K.Lee, **J.E.Son, S.D.Kim	*Kunkuk Univ., **KIER, KAIST
Particles size change in a thermobalance and a FBC reactor	*S.H.Lee, S.D.Kim	*KIER, KIST
Steam Gasification of the sludge and waste tire mixture in a ICFB with a draft tube.	*B.H.Song, S.D.Kim	*Kunsan Univ., KAIST
Gas bypassing fraction and solid circulation rate in a square ICFB	J.H.Chen, S.D.Kim	KAIST
Prediction of bed agglomeration in a fluidized bed combustor	K.H.Kim, J.H.Lim, J.K.Lee, *W.H.Kim	Bukyung Univ. *KIMM
Solid dispersion in a gas-liquid-solid inverse fluidized bed	H.T.Kim, S.H.Kang, Y.Kang, *S.D.Kim	ChungNam Univ. *KAIST
Hydrodynamic study in a liquid-solid CFB reactor	S.H.Kang, S.M.Son, P.S.Song Y.Kang, *S.D.Kim	ChungNam Univ. *KAIST
Molten salt oxidation of chlorinated plastics and rubber	H.C.Yang, Y,J.Cho, J.H.Yoo, J.H.Kim	KAERI

Nozzle characteristics of a CFB boiler	Y.J.Choi, Y.S.Kim, J.D.Hwang, M.S.Baek, K.H.Moon	Doosan Heavy Industry
Development and operation of cold model CFB reactor	J.D.Hwang, Y.J.Choi, Y.S.Kim, M.S.Baek, K.H.Moon	Doosan Heavy Industry
Co-combustion of Korean anthracite and bituminous coal in a CFB reactor	J.M.Lee, J.S.Kim, J.J.Kim	KEPRI

PORTUGAL

News

Presently there is no new development in fluidised bed applications in Portugal. INETI is about to receive a financial support from the government to install a 2.5 MWth unit in a company burning a mixture of waste materials. The boiler is currently under construction.

Commercial installations

owner/ location	year	type	capacity	fuels
COMBUSTORS				
CAIMA	1999	BFBC	25 MW	Bark, wood
R.I. Pneus	2000	BFBC	4 MWth	Waste tyres
GASIFIERS				
Portucel	1988	CFBG	20 MW	Bark

BFBC bubbling fluidized bed combustor
CFBG circulating fluidized bed gasifier

Research centers

In Portugal, research on fluidized bed combustion and gasification is carried out mainly at the **INETI** at the Department of Energy Engineering and Pollution Control. There is also combustion work at the following organisations:

1. University of Aveiro, Departamento de Engenharia do Ambiente
2. University of Porto, Departamento de Engenharia Química
3. INEGI, Porto

Companies

4. **MORISA,** Porto

SPAIN

Introduction

Research carried out at Spanish laboratories in 2003, in relation to the fluidised bed technology, has been directed to the areas of:

- Co-combustion of coals and biomass
- Modelling of co-combustion
- Modelling of mixing solids
- Wastes incineration
- Biomass and wastes gasification.

The interest is increasing on using fluidised bed technology for burning or co-firing wastes with coal. The wastes included all type of biomass (crops, agriculture by-products, forest residues) and other energetic wastes such as tired , ASR (auto sheered residues), etc.

Research centers

In Spain research on fluidised bed combustion and gasification is carried out at different laboratories belong to government institutions. See table I.

Table I.- Institutions interested on fluidised be combustion and gasification

INTITUTION	MAIN ACTIVITY	TYPE OF INTEREST
CIEMAT(Madrid)	Research Institute	Fundamental and applied research
COAL CHEMISTRY INSTITUTE (Zaragoza)	Research Institute	Fundamental and applied research
CHEMICAL ENGINEERING FACULTY (Madrid)	Public University	Fundamental and applied research
CHEMICAL ENGINEERING FACULTY (Zaragoza)	Public University	Fundamental and applied research
INDUSTRIAL ENGINEERING SCHOOL (Sevilla)	Public University	Fundamental and applied research

Table II.- Fluidised bed technology plants that at this moment are running in Spain.

PlANT NAME	TYPE	OBJETIVE	FUELS
ESCATRON (Teruel)	PFB	Electricity production (80MWe)	Coal (lignite)
LA PEREDA	CFB	Electricity production (50MWe)	Mine byproductcs

(Asturias)			and coal
TIRMADRID (Madrid)	BFB	Incineration wastes (20Mwe)	Municipal wastes
SOGAMA (La Coruña)	CFB	Incineration wastes (50Mwe)	Municipal wastes
CIEMAT (Soria)	BFB	Incineration wastes (Demostration plant (3.6 MWth))	Several wastes and biomass

Journal Publications

"Effect of moisture content on devolatilization times of pine wood particles in fluidized bed"
L.F. de Diego, F. García-Labiano, A. Abad, P. Gayán, J. Adánez
Energy & Fuels, 17(2), pp.285-290 (2003)

"Combustion of wood chips in CFBC. Modelling and validation"
J. Adánez , P. Gayán , L.F. de Diego, F. García-Labiano, A. Abad
Ind. Eng. Chem. Res. 42 (5) pp.987-999 (2003)

"Circulating fluidised bed co-combustion of coal and biomass"
P. Gayan, J. Adanez, L. F. de Diego, F. García-Labiano, A. Cabanillas, A. Bahillo, M. Aho, K.Veijonen.
Fuel 83 (3) pp.277-286 (2004)

"Co-combustion of coal and olive oil industries residues in fluidised bed."
L. Armesto, A. Bahillo, A. Cabanillas, K.Veijonen, J. Otero, A. Plumed, L. Salvador
Fuel 82 (2003) 993-1000

"N_2O emissions from fluidised bed combustior. The effect of fuel characteristics and operating conditions"
L. Armesto, H. Boerritger, A. Bahillo , J. Otero
Fuel 82 (2003) 1845 – 1850

" Emission particles from combustion of leather waste in BFB"
JL Dorronsoro, JJ Rodriguez-Maroto, D. Sanz, L. Armesto, A. Bahillo
Journal of Aerosol Science 2003, S1295-1296

"Conversion limits in the reaction of CO2 with lime"
J C Abanades, D. Alvarez.
Energy and Fuels, Vol 17, 2, 2003, 308-315

"Progress of Sulfation in Highly Sulfated Particles of Lime"
J. C. Abanades, E. J. Anthony, F.García-Labiano, L. Jia,
Ind. Eng. Chem. Res. 2003, 42, 1840-1844

Congress papers

Co-combustion of biomass and coal in circulating fluidized beds. Modeling and validation.
J. Adánez, L.F. de Diego, P. Gayán, F. García-Labiano, A. Cabanillas, A. Bahillo.
17th International Conference on FBC, ASME, Jacksonville, USA (2003)

Modelling co-combustion of wood and coal in circulating fluidized beds.
J. Adánez, L.F. de Diego,P.Gayán, F. García-Labiano, A. Cabanillas, A. Bahillo, M. Aho, K. Veijonen. Chemical industry and environment IV, ed. A. Macías Machín, J. Umbría, Universidad de Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Spain (2003) pp. 223-232

New trends on combustion gases treatments.
J. Adánez, F. García-Labiano, L.F. de Diego, P. Gayán.
4th European Congress of Chemical Engineering, Granada, España (2003)

In-situ capture of CO2 in a fluidized bed combustor.
J.C. Abanades, E.J. Anthony, D Alvarez, D.
17th International Conference on FBC, ASME, Jacksonville, USA (2003)

A simulation study for fluidized bed combustion of petroleum coke with CO2 capture.
J. Wang, E.J. Anthony, J.C. Abanades
17th International Conference on FBC, ASME, Jacksonville, USA (2003).

SWEDEN

In the yearly report from 2002 the extensive installations at the Chalmers Power Station to supply various kinds of fuels to the CFB boiler were described. As a result the new installations, there are now four parallel fuel-feed systems: two for conventional coal and biomass co-firing and two additional systems for extreme fuels, such as mechanically dried (wet) sludges. These systems have been employed during 2003 for a comprehensive study on the behaviour of sludges, not only of municipal origin as before, but also from industrial processes, especially from the pulp and paper industry.

Sludges from eight paper mills were included, basically consisting of three types: fibre sludge, sludge produced through chemical sedimentation and biologically cleaned material. The latter is most similar to municipal sludge that was also included for comparison. In Sweden there is a commercial method for solar drying of sludge under development, and a few dried sludges from such a process were also tested. The sludges may contain considerable quantities of sulphur and nitrogen, and methods to reduce the corresponding emissions by addition of various kinds of lime, but also by addition industrial rest products, were investigated. The choice of base fuel for co-combustion, wood, was made because this would be the normal base fuel in the pulp and paper industry, but also to get a low-emission background for the study of the emission behaviour from the sludge.

The principal investigator, Dr L.-E. Åmand, getting acquainted with the feeding properties of fibre sludge in the external fuel-feed hopper.

The principal goals of the investigation were to obtain experience on the design of handling systems for the various materials (Despite the common denomination, sludge, the reological properties of the various types of sludge differ a great deal), and to get data on emission behaviour and on emission reduction.

Two preliminary reports from the sludge work have been published [1][2].
Another activity deals with combustion in the bottom bed, as illustrated by the following figure.

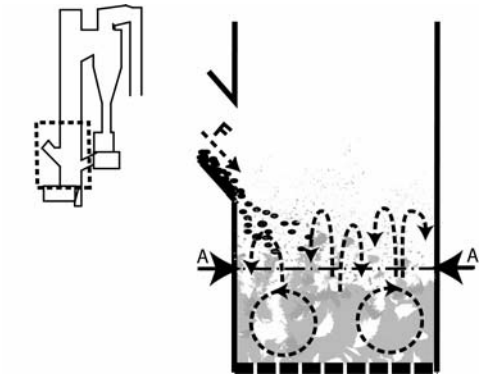


Figure. The bottom part of the Chalmers CFB boiler operated in non-circulating mode for studies of mixing and combustion in the bottom bed.

The boiler was then operated in the non-circulating mode, which is achieved by increasing the pressure drop through the bottom air nozzles and modifying the fluidization velocity to the range common in this type of combustors. The problem studied concerns combustion of biofuel in non-circulating bed. In this application the heat balance of the bottom bed and splash zone is decisive to predict the bed temperature, and the interchange of energy between the dense bed, the splash zone and the freeboard has to be deterimned. The results are presently under preparation and will be submitted for a doctor's disputation in 2004. A special study was dedicated to the injection of secondary air and mixing in the freeboard. A general account for the work was mentioned by Johnsson [3] at the IEA Technical Meeting in Turow. An initial work deals with mixing of fuel in the bed and the related dispersion coefficients. The results from this part of the work have been published during the year 2003 [4].

References

1. Åmand L.-E., Leckner B., Herstad-Svärd S., Gyllenhammar M., Eskilsson D., Tullin C., Co-combustion of pulp and paper sludge with wood--emissions of nitrogen, sulphur and chlorine compounds, Proc. of the 17th International Fluidized Bed Combustion Conference, Paper FBC2003-097, Ed. S.V.Pisupati, ASME, New York, 2003.

2. Åmand L.-E., Leckner B., Hansson L., Norrlöw O., Co-combustion of municipal sludge with wood/coal in CFB--enrichment of phosphourous and cadmium in ashes, Proc. of the 17th International Fluidized Bed Combustion Conference, Paper FBC2003-098, Ed. S.V.Pisupati, ASME, New York, 2003.

3. Johnsson F. Mixing and flow structures in fliudized bed boilers, IEA Technical Meeting, Turow Power Station, Poland 2003.

4. Niklasson F, Johnsson H, Leckner B., Local air ratio measured by zirconia cell in a circulating fluidised bed furnace, Chem. Eng. J. **96** (1-3): 145-155, 2003