



*International Energy Agency*  
*Fluidised Bed Conversion*

***Year report 2002***



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

**TABLE OF  
CONTENTS**

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**TABLE OF CONTENTS**

<b>TABLE OF CONTENTS</b> .....	1
<b>INTRODUCTION</b> .....	2
<b>COUNTRY REPORTS</b> .....	4
<b>AUSTRIA</b> .....	5
<b>CANADA</b> .....	7
<b>FINLAND</b> .....	9
<b>FRANCE</b> .....	12
<b>ITALY</b> .....	14
<b>JAPAN</b> .....	16
<b>KOREA</b> .....	19
<b>PORTUGAL</b> .....	21
<b>SPAIN</b> .....	22
<b>SWEDEN</b> .....	25

### **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, Italy, Japan, Korea, Portugal, Spain, Sweden and United Kingdom. In October 2002 Greece joined the Implementing agreement.

Fluidized beds offer several advantages over pulverised fuel combustion, notably low NO<sub>x</sub> emission, in-process capture of SO<sub>2</sub> 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
- NO<sub>x</sub> and N<sub>2</sub>O 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.

## *INTRODUCTION*

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### **MEMBERCOUNTRIES**

<b>Member countries</b>	<b>Contracting parties</b>	<b>Contact person</b>
Austria:	University of Vienna	Franz. WINTER
Canada	CETC-NRC	E.J. (Ben) ANTHONY
Finland	Åbo Akademi University	Mikko HUPA
France	ÉDF-DER	Philippe JAUD
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:**

University of Vienna, Franz Winter (until May 2002)

Åbo Akademi University, Mikko Hupa (from May 2002 onwards)

### **EVENTS**

44<sup>th</sup> IEA-FBC meeting held on May 27-28<sup>th</sup>, 2002 in Vienna, Austria

The meeting consisted of a technical session and a workshop on "Fuel Interaction & Future Fuel Mix"

16 papers were presented and the 8 MW FICFB Gasifier in Güssing was visited.

45<sup>th</sup> IEA-FBC meeting held on November 18-19<sup>th</sup>, 2002 in Prague, Czechoslovakia

The meeting consisted of a technical session and a workshop on "Difficult fuels, opportunity fuels and fuel mixtures in FBC".

14 papers were presented and the power plant TISOVA was visited

**COUNTRY REPORTS**

## AUSTRIA

### News

A new fluidized bed combustor for sewage sludge and wood residues is currently under construction at EBS/Vienna. A rotating fluidized bed (RFBC) was chosen for this purpose.

The new biomass CHP-plant based on fluidized bed gasification is in operation in Güssing, Burgenland. The capacity is 8 MW and the plant supplies 4,1 MW<sub>th</sub> heat into a district heating system and 2,0 MW electricity into the grid. The fuels are wood chips and residues from a wood working industry. The gas coming from a steam blown dual fluidized bed gasifier is cleaned and fed into a gas engine. (For further details see [www.renet.at](http://www.renet.at))

### 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

## *AUSTRIA*

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The table contains the most important features of fluidized bed combustors and gasifiers currently in operation.

### **Research centres**

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

- Institute of Chemical Engineering, Fuel Technology and Environmental Technology, Getreidemarkt 9/159, A1060 Vienna
- Institute of Thermal Engineering, Getreidemarkt 9/302, A1060 Vienna
- Institut für Apparatebau, Mechanische Verfahrenstechnik und Feuerungstechnik, Infeldgasse 25/B/I, A-8010 Graz

### **Companies**

- AE Energietechnik
- Verbundgesellschaft
- Repotec

## CANADA

### **FBC and Gasification Research at CETC**

Fluidized bed combustion and gasification research carried out at CETC laboratories in 2002 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 British Columbia, the University of Toronto, the Technical University of Vienna, Cracow University of Technology, the University of Naples (Frederico II), and the Instituto de Carboquímica in Spain. This work has led to a series of journal and conference publications that are listed below. CETC also completed a 5-year contract with Syncrude Canada, simulating a fluid coker with its twinned CFBC and BFBC reactors. Recent work was directed toward process optimization using vacuum topped bitumen as feedstock. 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 PiZon 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. A study of FBC/gasification of waste-derived fuels, for EPIC. This study evaluated the combustion and gasification of separated fractions of waste-derived fuel with respect to a complete fuel and emissions characterization, and the results will be submitted for publication and presentation at the 2003 ASME FBC conference.
6. 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.
7. R&D program to optimize performance of the AIRborne Process. This process uses sodium bicarbonate sorbent to capture SO<sub>2</sub> and NO<sub>x</sub> from utility flue gases. Novel features include regeneration of the sorbent and production of by-product fertilizer. Results of the R&D program will be applied at a demonstration plant in Kentucky.
8. Combustion of coal/water slurries (CWS) in a FBC for the University of Southern Illinois Carbondale.
9. 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. Anthony, E.J., Bulewicz, E.M., Dudek, K. and Kozac, A., "The Long Term Behaviour of CFBC Ash-Water Systems", Waste Management Journal, 22, 99-111, 2002.



2. Jia, L., Anthony, E.J. and Charland, J.P., "Investigation of Vanadium Compounds in Ashes from a CFBC Boiler", *Energy and Fuels*, 16, 397-403, 2002.
3. Anthony, E.J., Lu, D.Y. and Zhang, J.Q., "Combustion characteristics of heavy liquid fuels in a bubbling fluidized bed", *Journal of Energy Resources Technology*, 124 (1), 40-46, 2002.
4. Wu, Y.H., E.J. Anthony, and Jia, L., "An Experimental Study of Hydration on Partially Sulphated FBC Ash", *Combustion Science and Technology*, 174, 171-182, 2002.
5. Anthony, E.J., Jia, L., Cyr, L., Smith, B. and Burwell, S., "The Enhancement of Hydration by Fluidized Bed Combustion by Sonication", *Environmental Science and Technology*, 36, 4447-4453.

### Conference Papers

1. D.Y. Lu and E.J. Anthony, "Combustion of natural gas in fluidized bed combustion", 2002 Spring Technical Meeting of the Combustion Institute, Canadian Section, Windsor, Canada, May 12-15, 2002.
2. D.Y. Lu and E.J. Anthony, "Emissions from natural gas combustion in a circulating fluidized bed", AFRC 2002 Spring Meeting, Ottawa, Canada, May 08-10, 2002.
3. D.Y. Lu and E.J. Anthony, "Aspects of cofiring natural gas in fluidized bed combustion", 27th Int. Technical Conference on Coal Utilization & Fuel Systems, Clearwater, Florida, March 7-10, 2002.
4. E.J. Anthony, L. Jia and K. Qiu, "CaS Oxidation by Reaction with CO<sub>2</sub>", Proc. 6th European Conference on Industrial Furnaces and Boilers, April, 2002, Lisbon, Portugal.
5. J. Wang, L. Jia. and E.J. Anthony, "A Study on N<sub>2</sub>O Formation in Flue Gas", 2002 Spring Technical Meeting of the Combustion Institute, Canadian Section, Windsor, Canada, May 12-15, 2002.
6. Jia, L. and Anthony, E.J., "The Combustion of Stoker Ash in a CFB", Proceedings of the 7<sup>th</sup> International Conference on Circulating Fluidized Beds, Niagara Falls, Ontario, Canada, pp. 701-708, May 12 2002.
7. Ziock, H.-J., 1, Garzon, F.H., Brosha, E.L., Mukundan, R., Smith, B.F., Robison, T.W., Roop, B.J., Guthrie, G.D., Johnson, .A.A, Lackner, K.S., Lau, F., E.J. Anthony, E.J., Wang, J., Ruby, J., "Technical Progress in the Development of Zero Emission Coal Technologies", Pittsburgh Coal Conference, 19<sup>th</sup> Annual Pittsburgh Coal Combustion, Conference, September 23-27, 2002.

### Book Chapters

1. L. Jia, E.J. Anthony and D.L. Granatstein, "Dioxin and Furan Formation in FBC Boilers", Chapter in M. Maroto-Valer (ed.), *Environmental Challenges and Greenhouse Gas Control for Fossil Fuel Utilization in the 21st Century*, Kluwer Academic/Plenum Publishers, 2002.

## **FINLAND**

### **Overview**

Fluidized bed conversion has continued to play an important role in the Finnish energy economy. A number of installations have been in production for a first full year. 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 2002 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, and CODE 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. CODE dealt with modeling of furnaces and combustion processes. FBC processes are of great importance in the CODE program.

Also projects have been financed within the 5th 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  
Lappeenranta University of Technology  
Åbo Akademi University

### **Largest companies**

Foster Wheeler Oy, Kvaerner Pulping Oy

**FINLAND**

**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		
2000	Voimavasu Oy Salo Finland	32	11	63	510	Peat, wood residue, recovered fuel	
2001	Turku Energia Turku Finland	40	-	16	204	Wood residue, chips, bark	Hot water boiler
2001	Vamy OY / Vattenfall OY Anjalankoski Finland	88	36	115	525	Bark, biosludge, natural gas, peat, wood residue	
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	

**B. Bubbling fluidized beds by Kvaerner Pulping**

Delivery year	Costumer/site	Capacity MWt	Steam data			Fuels	Remarks
			Flow kg/s	Press. bar	Temp. °C		
2001	Kokkolan Voima OY Kokkola Finland	70	27	80	482	Wood waste, peat	
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	

**FINLAND**

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**C. Circulating fluidized beds by Kvaerner Pulping**

Delivery year	Customer/site	Capacity MWt	Steam data			Fuels	Remarks
			Flow kg/s	Press. bar	Temp. °C		
2001	Oy Ahlholmens Kraft AB Pietersaari Finland	550	194/179	1165/40	545/545	Wood waste, peat, sludge, coal	

**FRANCE**

**Introduction**

Today, the main french electricity producers involved in FBC research and Development are EDF (Electricite de France) and SNET (Société Nationale d'Electricité et de Thermique). Two manufacturers are also carrying out research for the development of FBC technology : ALSTOM and CNIM (Construction Industrielles de la Méditerranée). Several french universities are also involved in research and development.

**Commercial installations**

owner/ location	year	type	capacity	fuels
<b>COMBUSTORS</b>				
Soprolif/ Gardanne	1995	CFBC (Alstom)	250 MWe	Gardanne coal
City of Grenoble/ Grenoble	1993	CFBC (FW)	20 MWe cogeneration	Coal
Golbey pulp & paper/Golbey	1991	BFBC (FW)	44.5 MWth	Wood residues, sludge,
Sodelif/ Carling	1990	CFBC (Alstom)	125 MWe	Coal slurry
Starcel pulp & paper/ Stracel	1990	BFBC (FW - CNIM)	30 MWth	Bark, sludge, oil
Cofreth/ Massy	1990	CFBC (FW - CNIM)	2 x 10 MWe cogeneration	Coal, oil
Somedith/ Marseilles	1988	CFBC	50 MWth cogeneration	Coal
SIVOM/ Sausheim	1999	FICFBC (Ebara - Lurgi)	2 x 11 t/h	Municipal wastes
CIDEME/ Gien	1997	FICFBC (Ebara - Lurgi)	2 x 5 t/h	Municipal wastes
VALENE/ Mantes	1997	BFBC (TMC)	3 x 4 t/h	Municipal wastes
VALNOR/ Doullens	?	BFBC (TMC)	1 x 3 t/h	Municipal wastes
SMITOM/ Monthyon	?	BFBC (TMC)	1 x 4 t/h	Municipal wastes

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

The table contains the most important features of fluidized bed combustors currently in operation.

## *FRANCE*

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### **Research centers**

In France research on fluidized bed combustion and gasification is carried out mainly at the:

1. EDF R&D, 6 quai Watier, 7400 Chatou, France
2. CERCHAR, BP 19, 62670 Mazingarbe, France

### **Companies**

1. ALSTOM
2. CNIM

*ITALY*

**ITALY**

**Commercial installations**

<b>OWNER/LOCATION</b>	<b>START-UP</b>	<b>TYPE</b>	<b>CAPACITY</b>	<b>FUEL</b>
<b>ENEA Casaccia</b>	-	BFBC	1,5 MWth	RDF
<b>ACCAM Busto Arstizio</b>	1999	BFBC	Pilot plant	RDF
<b>FERRERO SpA Macomer</b>	August 1994	2 x FICFBC	2 MW	RDF
<b>AREA Ravenna</b>	1999	BFBC	7 MW	RDF
<b>Cartiere Burgo Mantova</b>	1999	BFBC	3,2 MW	Paper sludge
<b>ENI Scarlino</b>	1999	BFBC	3 x 6 MW	RDF
<b>Sicet Ospitale di Cadore</b>	1999	CFBC	17,5 MW	Wood, Bark
<b>Termomeccanica Lucca</b>	1999	BFBC	2x12 MW	RDF
<b>ENI Porto Marghera</b>	2000	BFBC	2 x 14 MWth	Refused oil
<b>Lomellina Energia Parona</b>	2000	CFBC	15 MW	RDF
<b>Cartiere Burgo Verzuolo</b>	2001	BFBC	7 MW	Paper sludge
<b>BAS Bergamo</b>	2002	CFBC	10 MW	RDF
<b>Appia Energy Massafra</b>	2003	CFBC	10MW	RDF.
<b>BiomasseItalia Strongoli</b>	2003	CFBC	2 x 20 MW	biomass
<b>Ecoenergia Corteolona</b>	2003	<b>BFBC</b>	30 MWth	RDF
<b>Euroenergy Cutro</b>	2003	<b>BFBC</b>	14 MW	Wood chips
<b>Termomeccanica Calabria</b>	2003	<b>BFBC</b>	2x30MWth	RDF
<b>ENEL Produzione Sulcis</b>	20045	<b>CFBC</b>	340 MW	Coal

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**

<b>INSTITUTION OR COMPANY</b>	<b>OWNER</b>	<b>MAIN ACTIVITY</b>	<b>TYPE OF INTEREST IN FBC</b>
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**

<b>COMPANY</b>	<b>OWNER</b>	<b>FBC PRODUCTS</b>
CCT	Gruppo Marcegaglia	<ul style="list-style-type: none"> <li>• Industrial Boilers</li> <li>• Heat Recovery Steam Generators</li> <li>• Waste to Energy Boilers</li> <li>• Fluidized Bed Combustors (EPI license)</li> <li>• Gasification Systems</li> </ul>



## **JAPAN**

### **News**

Electric Power Development Corporation Limited (EPDC) began operation of the world's largest atmospheric pressure fluidized bed combustion boiler (AFBC) at their 350MW No. 2 Takehara Power Station in 1995, which continues to function normally today.

At the Wakamatsu Coal Utilization Laboratory, EPDC also completed government sponsored test runs on a 71MW test plant utilizing a pressurized fluidized bed combustion boiler (PFBC) in March 2000. Commercial power stations utilizing PFBC in Japan include the 85MW No. 3 Tomatoh-Atsuma Thermal Power Station (Hokkaido Electric Power Co. Inc.), operational since 1998, the 250MW No. 1-1 Osaki Power Station (The Chugoku Electric Power Co. Inc.), since 2000, and the 360MW No.1 Karita Power Station (Kyushu Electric Power Co. Inc.), since 2001.

Japan has also undertaken research on an advanced PFBC (A-PFBC) which re-fires non-gasified char in a separate PFBC to create additional gas for driving the steam turbine. Test runs on a 5MWth station have been made at EPDC's Wakamatsu Coal Utilization Laboratory.

In this system, the net thermal efficiency is expected to be more than 46% (HHV).

Test runs started in July 2001, and 15 test runs were carried out by November 2002.

Examination about the characteristic of partial gasification, desulfurisation and combustion of char in various operation conditions is performed.

In general industry sectors in Japan, a total of 35 bubbling fluidized bed combustion boilers (BFBC) and 24 circulated fluidized bed combustion boilers (CFBC) are being used in in-house generators and for process steam. Coal is the main source used for firing, but other fuels including petroleum coke, refuse derived fuels, pulp sludge, waste wood, industrial waste, and waste water sludge are also in use.

**JAPAN**

**Commercial installations**

(Data from 1990 and excluding tiny facilities)

owner/location	year	Type	capacity	fuels
Toyota Motor Corporation/ Aichi	1990	Circulating FBC	16MW (Evaporation:70t/h)	Coal, Industrial Waste
Oji Paper Co., Ltd/ Hokkaido	1990, 4	Circulating FBC	10MW (Evaporation:150t/h)	Coal, Pulp Sludge
Kobe Steel, Ltd/ Hyogo	1990, 6	Circulating FBC	50MW (Evaporation:225t/h)	Coal, LPG
Mitsubishi Chemical Corporation/ Fukuoka	1991, 7	Circulating FBC	62MW (Evaporation:250t/h)	Coal, Heavy Oil, Byproduct Gas
Nippon Paper Industries Co., Ltd/ Hokkaido	1992	Bubbling FBC	10MW (Evaporation:45t/h)	Coal, Pulp Sludge
Omikenshi Co., Ltd/ Mie	1992, 6	Circulating FBC	7MW (Evaporation:30t/h)	Coal, Heavy Oil
Taiheiyo Cement Corporation/ Hokkaido	1993, 4	Circulating FBC	? (Evaporation:180t/h)	Coal, Heavy Oil
Mazda Motor Corporation/ Yamaguchi	1993, 6	Circulating FBC	21.5MW (Evaporation:88t/h)	Coal, Heavy Oil
Nippon Paper Industries Co., Ltd/ Hokkaido	1994, 10	Circulating FBC	31.4MW (Evaporation:260t/h)	Coal, Heavy Oil
Takasaki Sanko Paper Co., Ltd/ Aichi	1994, 12	Circulating FBC	20MW (Evaporation:120t/h)	Coal, Heavy Oil
Electric Power Development Co., Ltd/ Hiroshima	1995	Bubbling FBC	350MW	Coal
Tore Industries Inc./ Aichi	1995, 10	Circulating FBC	25MW (Evaporation:120t/h)	Coal, Heavy Oil
Taiheiyo Cement Corporation/ Saitama	1996, 4	Circulating FBC	? (Evaporation:178t/h)	Coal, Petroleum Coke, RDF
Taiheiyo Cement Corporation/ Oita	1996, 4	Circulating FBC	29MW (Evaporation:96t/h)	Coal, Petroleum Coke, RDF
Kyushu Electric Power Co., Inc/ Fukuoka	1996, 5	PFBC	360MW (Evaporation:760t/h)	Coal
Taiheiyo Cement Corporation/ Kochi	1997, 3	Circulating FBC	? (Evaporation:100t/h)	Coal, Petroleum Coke, RDF
Myojo Cement Co., Ltd/ Niigata	1997, 3	Circulating FBC	? (Evaporation:90t/h)	Coal, Petroleum Coke, RDF
Ube Industries, Ltd/ Yamaguchi	1997, 10	Circulating FBC	? (Evaporation:250t/h)	Coal, Petroleum Coke, RDF
Hokkaido Electric Power Co., Inc/	1998, 3	PFBC	85MW (Evaporation:195t/h)	Coal

*JAPAN*

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Hokkaido				
Sumitomo Cooperate Electric Co., Ltd/ Aichi	1999, 5	Circulating FBC	? (Evaporation:150t/h)	Coal
Sumitomo Osaka Cement Co., Ltd/ Kochi	1999, 7	Circulating FBC	? (Evaporation:230t/h)	Coal, RDF, TDF
Chugoku Electric Power Co., Inc/ Hiroshima	2000	PFBC	250MW (Evaporation:522t/h)	Coal
Taiheiyo Cement Corporation/ Niigata	2001, 6	Circulating FBC	? (Evaporation:475t/h)	Coal

**Research center**

Dr. Hiroshi Moritomi, Research Group of Fluidization Engineering, Society of Chemical Engineers, Japan (SCEJ)

4-6-19 kohinata, Bunkyo-ku, 112-0006 Tokyo

Fax: +81-3-3943-3530

**KOREA**

**News**

KEPRI starts a new research project, 'Study on Reduction of Unburned Carbon in Fly Ash and Optimal Design for the CFB boiler using Korean Anthracite', supported from KEMCO (Korea Energy Management Corporation) and Korea East-West Power Generation Corporation (July 2002 – June 2004). The project will be carried out with partners from industry and university, and will be continued for two years.

Construction project of new CFB boiler (Yong-Wol CFB boiler, 200MWe), projected by Korea Southern Power Corporation, is in progress and will be completed in Oct. 2005.

**Activities**

KIChE fall meeting was held on 24-26 Oct. 2002 at Seoul National University in Korea. In this meeting, there were 13 oral and 9 poster presentations related with FBC technology, and they are as follows:

Title	Authors	Affiliation
Attrition characteristics of Zinc Titanate sorbent	Y.S.Moon,* J.H.Choi,* C.K.Lee, J,I,Son	*Kunkuk Univ., KIER
The change of mean particle size due to jet attrition	S.H.Lee, S.D.Kim	KAIST
A study on improvement of incineration facilities for industrial wastes in Ansan city	Y.J.Cho	Ansan College
Degradation characteristics of Trichloroethylene with TiO <sub>2</sub> /SiO <sub>2</sub> in annulus fluidized bed photoreactor	T.H.Lim, S.D.Kim	KAIST
Chaos analysis of pressure fluctuation in aerobic three phase inverse fluidized beds	S.Y.Kim, H.T.Kim, P.S.Song, C.K.Lee, Y.Kang	ChungNam Univ.
Gas holdup and mass transfer in three phase circulating fluidized bed bioreactors	T,K.Kang, C.K.Lee, H.T.Kim, H.S.Choi, Y.Kang, *S.D.Kim	ChungNam Univ. *KAIST
Copper recovery from waste water of electronic industry in a liquid circulating fluidized bed reactor	P.S.Song, C.K.Lee, T,K.Kang, H.T.Kim, Y.Kang, *S.D.Kim	ChungNam Univ. *KAIST
Removal of N, P in seawater by zeolite	J.Y.Chong, S,W.Lee, K,H.Kim, J.H.Lim, J,K.Lee	Pukyung Univ.
Surface modification of HDPE powders by CF <sub>4</sub> plasma in a CFB reactor	S,H,Chong, S.D.Kim	KAIST
Catalytic pyrolysis of naphtha	S.M.Chong, J.H.Choi, J.H.Kang, S,K,Park, W,H,Lee	LG chemicals
Continuous operation of Zinc based sorbents in a Fluidized Hot Gas Desulfurization reactor	S.H.Cho, S.Y.Lee, C.K.Lee	KIER
Concept design of 50kWth chemical looping combustor	H.J.Ryu, D.H.Bae, S.Y.Lee, K.T.Jin	KIER
Optimum operation in gas phase fluidization reactor in LLDPE	S.W.Kim, W.M.Yang, C.H.Choi	Samsung Chemicals

## ***KOREA***

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Also, the 8<sup>th</sup> ASIAN CONFERENCE ON FLUIDIZED-BED AND THREE-PHASE REACTORS was held on Nov. 3-7, Bangkok, Thailand. Many Koreans (about 40 people) attended this conference and presented a number of papers related with FBC technology.

## **PORTUGAL**

### **News**

The use of renewable energies in Portugal is strongly encouraged at this moment and the program to provide financial incentives is particularly designed to promote renewable energies. In this respect, fluidised bed combustion could find applications for the use of biomass and non-toxic wastes to generate energy.

### **Commercial installations**

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

BFBC      bubbling fluidized bed combustor  
            circulating fluidized bed gasifier

CFBG

### **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**

1. MORISA, Porto

**SPAIN**

**News**

Research carried out at Spanish laboratories in 2002, 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 centres**

In Spain research on fluidised bed combustion and gasification is carried out at different laboratories belong to government institutions. See table 1.

**Table 1.- Institutions interested on fluidised be combustion and gasification**

<b>INTITUTION</b>	<b>MAIN ACTIVITY</b>	<b>TYPE OF INTEREST</b>
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

**Commercial installations**

**Table 2.- Fluidised bed technology plants that at this moment are running in Spain.**

<b>PIANT NAME</b>	<b>TYPE</b>	<b>OBJETIVE</b>	<b>FUELS</b>
ESCATRON (Teruel)	PFB	Electricity production (80MWe)	Coal (lignite)
LA PEREDA (Asturias)	CFB	Electricity production (50MWe)	Mine byproductes and coal
TIRMADRID (Madrid)	BFB	Incineration wastes (20Mwe)	Municipal wastes
SOGAMA (La	CFB	Incineration wastes (50Mwe)	Municipal wastes

Coruña)			
CIEMAT (Soria)	BFB	Incineration wastes (Demostration plant (3.6 MWth))	Several wastes and biomass

### Journal Publications

1. Armesto, L. Bahillo, A., Cabanillas, A. Veijonen, K., Otero, J. Plumed, A., Salvador, L. "Co-combustion of coal and olive oil industry residues in fluidised beds" *FUEL* (In press)
2. Armesto, L., Boerrigter, H., Bahillo, A., Otero, J. (2002) "N<sub>2</sub>O Emissions on FBC. Effect of the Fuel Characteristics" 4<sup>th</sup> UK Meeting on Coal Research and its Application (UK).
3. Armesto, L., Boerrigter, H., Bahillo, A. Otero, J. "N<sub>2</sub>O Emissions from Fluidised Bed Combustor. The effect of Fuel Characteristics and Operating Conditions" *FUEL*, in pres
4. G Grasa, J C Abanades , "The use of two different models to describe the axial mixing of solids in fluidised bed. Chem. Engr. Sci. Volume 57 (14) (2002) 2791-2798
5. García-Ibañez, P., Cabanillas, A. Gasification of leached orujillo (olive oil waste) in a pilot plant circulating fluidised bed reactor. Preliminary results, to have been submitted - November 2002- for publication in *Biomass and Bioenergy*
6. Gutierrez,F.J.; Ollero, P.; Cabanillas, A.; Otero, J. " A technical pilot plant assessment of flue-gas desulfurisation in a circulating fluidised bed" *Adv. Environ. Res.* 7 (2002) pp.73-85
7. J C Abanades, "The maximum capture efficiency of CO<sub>2</sub> using a carbonation/calcination cycle of CaO/CaCO<sub>3</sub>". *Chem. Eng. J.* Volume 4093 (2002), pages 1- 4
8. L.F. de Diego, F. García-Labiano, A. Abad, P. Gayán, and J. Adánez."Coupled drying and devolatilisation of non-spherical wet pine wood particles in fluidized beds". *Journal of Analytical and Applied Pyrolysis*, 65 (2002) 173-184
9. L.F. de Diego, F. García-Labiano, A. Abad, P. Gayán, and J. Adánez " Modelling of the devolatilization of nonspherical wet pine wood particles in fluidized beds". *Ind. Eng. Chem. Res.*, 41 (2002) 3642-3650.

### Conference Papers

1. Armesto, L., Otero, J., Boerrigter, H. (2002) "N<sub>2</sub>O Emissions Reduction by Using Biomass as Secondary Fuel in Coal-Fired Circulating Fluidised Bed Combustion (CFBCs) 12<sup>th</sup> European Conference and Technology Exhibition of Biomass for Energy, Industry and Climate Protection (Netherlands)
2. García-Ibañez, P., Cabanillas, A., Sánchez, J.M. The first gasification tests of leached orujillo on a circulating fluidized bed gasifier. *Pyrolysis and Gasification of Biomass and Waste. The future for PGBW: status, opportunities and policies for Europe*, 29 September-1 October 2002, Strasbourg, France. Bridgwater, A.V. (Ed.), CPL Press, to be published soon
3. J C Abanades, John E. Oakey; D Alvarez; Jouni Hämäläinen , "Novel combustion cycles incorporating capture of CO<sub>2</sub> with CaO" 6<sup>th</sup> Congress on Greenhouse Gas Control Technologies- GHGT-6, IEA-Greenhouse Programme/Elsevier. Kyoto-Japan: October 2002
4. J. Corella, A. Sanz, J. M. Toledo. "Modeling circulating fluidized bed biomass gasifiers. 4: a pseudo-rigorous 1-dimensional model for stationary state. Some results". "Pyrolysis and gasification of biomass and waste expert meeting", Octubre 2002, Strasburgo, France (in press).
5. J. Corella, J. M. Toledo, M. P. Aznar. "Improving the modeling of the kinetics of the catalytic tar elimination in biomass gasification". *Ind. Eng. Chem. Res.* 2002, 41 (14), 3351-3356.
6. J. Corella, J. M. Toledo, M. P. Aznar. "Improving the modeling of the kinetics of the catalytic tar elimination in biomass gasification" in "Power production from waste and biomass IV". Ed. by VTT, Espoo, Finlandia, [ISBN: 951-38-5734-4]. 2002, 313-332.



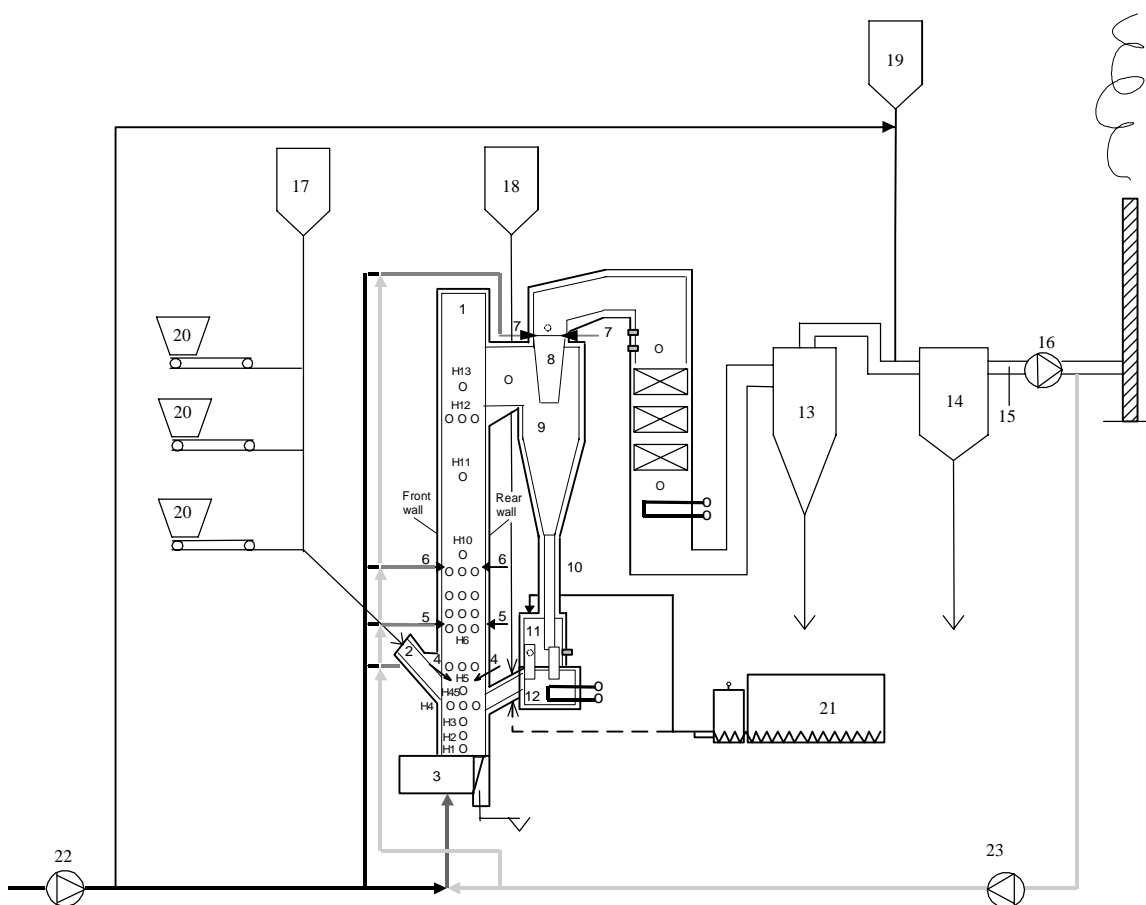
7. J. Corella, J. M. Toledo, R. Fernández. “Incineration of waste containing chlorine: Catalytic hot flue gas cleaning with total oxidation catalysts”. “5th International Symposium on Gas Cleaning at High Temperature (Sesion 8)”, Septiembre **2002**, Morgantown, West Virginia, USA.
8. J. Corella, J. M. Toledo, R. Fernández. “Waste incineration in fluidized bed: Testing total oxidation catalysts at pilot scale for gas clean up”. “IT3 Conference”, Mayo **2002**, New Orleans, Louisiana, USA.
9. J. Corella, M. A. Caballero, M. P. Aznar, C. Brage. “ Advanced kinetic model for the variation of the tar composition in its catalytic elimination in biomass gasification. “Pyrolysis and gasification of biomass and waste expert meeting”, Octubre 2002, Estraburgo, Francia (in press).
10. J. Corella. “Modeling a CFB biomass gasifier. Part IV: Model solution. Results and checking”. In “12th European Conference on *Biomass for Energy, Industry and Climate Protection*”. Ed. por W. Palz, J. Splitzer, K. Maniatis, [ISBN: 88-900442-5-X], **2002**, Amsterdam, 922-926.
11. M. P. Aznar, J. Corella, J. M. Toledo. “Checking an advanced 6-lump model for the kinetics of the variation of the tar composition in its catalytic elimination in biomass gasification”. In “12th European Conference on *Biomass for Energy, Industry and Climate Protection*”. Ed. por W. Palz, J. Splitzer, K. Maniatis, [ISBN: 88-900442-5-X], **2002**, Amsterdam, 927-930.
12. W. Zhang, C. Yu, J. Corella, H. Liu... “Process simulation of circulating fluidized beds with combustión/gasification of biomass”. In “12th European Conference on *Biomass for Energy, Industry and Climate Protection*”. Ed. por W. Palz, J. Splitzer, K. Maniatis, [ISBN: 88-900442-5-X], **2002**, Amsterdam, 749-753.

SWEDEN

News

The 12 MW CFB boiler at Chalmers University of Technology has been used extensively during the year 2002 for tests of co-combustion of coal and biofuels with wastes, especially sludge. Several sludges have been investigated, both mechanically dewatered and dried, of municipal as well as of industrial origin. For this purpose the research plant has been supplied with new equipment for simultaneous feeding of several fuels as illustrated in Figure 1.

Solid fuels can be fed from three parallel hoppers (20, Figure 1). This arrangement is especially useful for co-combustion experiments. Originally two of the three hoppers were built for coal. Later one of them was modified to handle biofuels, such as wood chips. Air-blasters were also installed to facilitate the flow of various fuels through the hoppers.



**Figure. 1** The 12-MW<sub>th</sub> CFB boiler at Chalmers University of Technology (1) combustion chamber; (2) fuel feed chute; (3) air plenum; (4) secondary air inlet at 2.1m; (5) secondary air inlet at 3.7m; (6) secondary air inlet at 5.4m; (7) secondary air inlet into cyclone exit duct; (8) cyclone exit duct; (9) hot primary cyclone; (10) particle return leg; (11) particle seal; (12) particle cooler; (13) cold secondary cyclone; (14) bag house filter; (15) gas-extraction probe for emission monitoring; (16) flue gas fan; (17) sand bin; (18) lime bin; (19) hydrated lime bin; (20) fuel bunkers; (21) Sludge pump (22) air fan; (23) flue gas recirculation fan.

The third, smaller, hopper (see also Figure 2) was installed to use dried sludge in addition to the other fuels. The properties of dried sludge are such that it can be handled in the other hoppers also, but the third hopper has some advantage in controlling dusting, and furthermore it increases the

flexibility of operation. Mechanically dewatered sludge has a high content of water, and although it is not fluid like a liquid, it has to be treated separately. This material is received from special containers and is then fed into a reconstructed cement pump (21) (shown on Figure 2) by means of which the sludge is pumped through a pipe (see Figure 2) to the particle seal (11) or directly into the cyclone return duct and from there to the combustion chamber.

The previously used feed system for limestone (18) has been completed with a system for injection of hydrated lime (19) just in front of the bag filter (see Figure 2). This method can be used to capture various pollutants from waste combustion, but it can also replace the conventional lime supply to the bed in such cases when comparisons of the bed material behaviour during co-combustion of coal and other fuels are to be made, and when the addition of lime to the bed could make comparisons difficult.

Several projects related to sludge have been run:

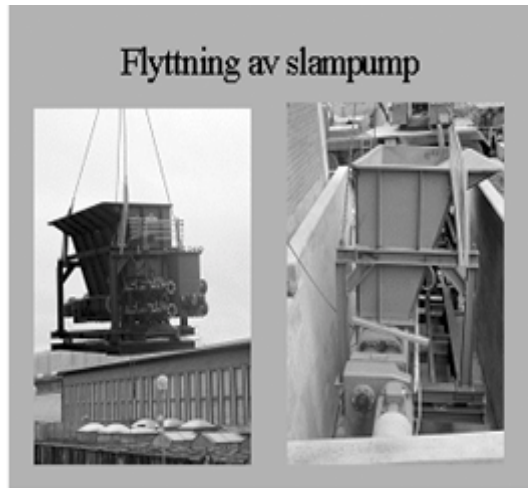
--Co-combustion of municipal sewage sludge from Ryaverket in Göteborg with coal and wood pellets. Coal and wood are compared as base fuels. Mapping has been carried out of the fate of heavy metals in ashes and in gaseous emissions.

--Co-combustion of municipal sewage sludge from Ryaverket and similar sludge from Alingsås with wood pellets as base fuel. This is a comparison between two sludges precipitated by different chemicals. In this project, like in the previous one, the behaviour of phosphorous has been studied because of the interest in using the sludge or the combustion ashes from sludge co-combustion as fertiliser. Then, the enrichment of heavy metals in relation to the content of phosphorous in the sludge or in the ashes becomes a critical issue. One of the reasons for using wood as a base fuel together with sludge is to attain the highest possible enrichment of phosphorous in the ash with insignificant dilution by ash from the base fuel

--Co-combustion of municipal sewage sludge from Ryaverket with waste wood and wood pellets. Again, the ashes and their content of heavy metals, especially zinc, an important constituent in paints, has been studied.

In summary, the interests are in investigating the role of the base fuel in co-combustion, the behaviour of wet or dried sludge and the consequences of these fuels and combinations of fuels on formation and destruction of 1) nitrogen and sulphur compounds 2) dust and heavy metals 3) dioxins and related substances. 4) alkali compounds in relation to chlorine and sulphur.

On the following page some figures are presented to illustrate the sludge pump, details from the fuel hoppers and the new system for injection of calcium hydroxide.



Installation of the sludge pump.



Freeze protected duct for sludge feed to the boiler.



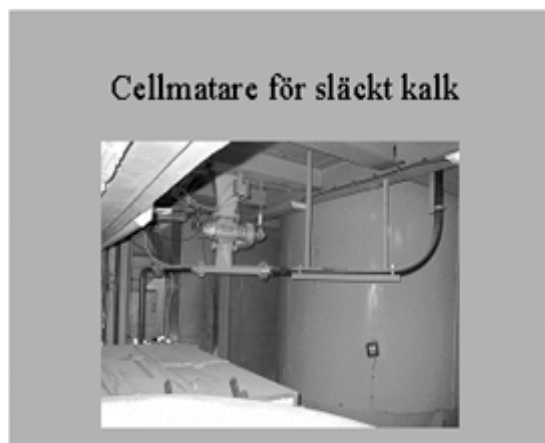
The third fuel hopper for dry sludge and other secondary fuels



Air blasters for the two main hoppers originally built for coal.



Feed point for calcium hydroxide upstream of the bag filter.



Cell feeder for calcium hydroxide.

Figure 2. Examples of equipment installed in the boiler plant for research purposes.