NEW WAYS TO SAVE ENERGY

Energy R&D and Demonstration Programmes of the Commission of the European Communities

Fluidized Bed Systems

Proceedings of the Contractors' Meetings held in Brussels on 12-13 October 1982

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P R E F A C E

The main objectives of the Community's energy policy are to secure an energy supply sufficient for the present and future demand of its Member States and to reduce the Community's dependence on imported energy through more rational use of energy and a broader diversification of supply. This requires a full set of common efforts at all levels, including energy research, development and demonstration.

In the framework of its strategy for scientific and technological research, the Commission of the European Communities has launched several R&D programmes in the field of energy. These programmes are implemented either directly in its Joint Research Centre or by concluding contracts with research institutions in the EC member countries.

One of the most important short and medium term objectives of the present four-year Energy R&D Programme (1979 - 1983) approved by the Council of Ministers on 13 September 1979 aims at fostering energy conservation technologies in the three main energy consuming sectors : domestic, industry and transport. In addition, under the Council Regulation EEC/ 1303/78 of 12 June 1978, the Commission grants financial support for Community demonstration projects in the field of energy saving.

In the European Community, 35% of the final energy is consumed by industry. About 23% of this energy is oil based. More than two-thirds of the energy is used for heating purposes. Therefore, the development of improved combustion processes and waste heat recovery have high priority in the Community's energy saving programmes. In view of the fact that the world coal resources are an order of magnitude larger than oil and gas resources, improved fluidized bed combustion and gasification techniques are being developed and applied by industry. Their main advantages are in particular high heat transfer, low SO_2 levels in fumes when limestone is added, reduced fouling and corrosion of heat transfer tubes, the possibility of burning low-grade fuel and reduced dimensions when compared with conventional coal-fired boilers.

A number of classical fluidized bed combustors working at atmospheric pressure are already in the demonstration stage, mainly in the USA, but general experience is not yet available. "Circulating fluidized bed combustion" eliminates a number of drawbacks of the classical fluidized bed combustors. Pressurized fluidized bed units offer a higher efficiency but their application depends on the development of a gas cleaning system and of an adequate high temperature gas turbine.

Although fluidized bed combustion is not expected to decrease the overall energy consumption, it allows the user to reduce his dependence on imported oil and gas, to provide for a better diversification of fuels and to comply with environmental requirements.

Fluidized bed techniques may also be used in heat exchangers for waste heat recovery, in particular for application in dirty and corrosive industrial fumes.

In order to enhance the rational use of energy and energy conservation in the Community, it is necessary, among other things, to promote the development and demonstration of fluidized bed combustors and fluidized bed heat exchangers. Therefore, the Commission has concluded with industries, public organizations and universities of the EC Member States a number of R&D contracts dealing with the development and demonstration of fluidized bed combustors and heat exchangers and their application. The progress of work achieved in these contracts was reported at this contractors' meeting, and the papers presented are collected in the proceedings volume in order to inform the Member States, research bodies and other interested parties about existing development work on fluidized bed combustors and heat exchangers.

Before ending these short introductory remarks, I would like to express my sincere gratitude to all the specialists who accepted invitations to take an active part in the work of this meeting by preparing a paper on specific topics.

Finally, I would like to express the hope that the work reported on during this contractors' meeting will contribute to rapid progress in the development and demonstration of fluidized bed combustors and heat exchangers, thereby helping to save energy and to reduce the Community's dependence on imported oil.

Dr. Albert STRUB

Director

Head of Energy R&D Programme

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DEMONSTRATION PROJECTS

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C O N T E N T S

SESSION II - FLUIDIZED BED HEAT EXCHANGERS

Contractors' meeting held on 12 October 1982

Chairman: J. CARRASSE

PART II - DEMONSTRATION PROJECTS

SESSION III - FLUIDIZED BED HEAT EXCHANGERS

Contractors' meeting held on 13 October 1982

Chairman: M. DAVIS

SUMMARY OF THE PROCEEDINGS

P. Zegers*, J. Carrasse** and J.A. Knobbout***

INTRODUCTION

In the European Community, R and D on fluid bed combustion is carried out in the second Energy R+D programme in Directorate General XII for Science, Research and Development. Fluidized bed demonstration projects are carried out in the frame of the Community demonstration programme for energy savings (DG XVII). On 12 and 13 October the contractors working on fluid beds in the Energy R+D programme and the Demonstration scheme were invited to present a paper on the progress of their work. Nine papers on R+D projects and ten papers on demonstration projects were presented. The proceedings of this two day contractors meeting are given in this book and below a summary will be given of the papers presented and the discussion.

STATE OF THE ART

Before discussing the progress of these projects a short description of the principles and state of the art of fluid beds will be given.

A fluid bed is basically a container with fine inert solid particles. In the bottom of the container holes are made through which air can be blown in upward direction. If the air velocity is high enough the particles can be lifted and float in the air in a turbulent motion which resembles a fluid. If this bed is brought at 700-900° C and preheated solid fuel is introduced, combustion takes place. Normally only 2-3 % of the fluid bed mass consists of fuel; other materials are inert particles and ash.
The heat released in the fluid bed can be removed in three ways :

- Heat can be extracted with heat transfer tubes in the bed (e.g. in order to heat air for gas turbines or to raise steam). The heat transfer in the fluid bed is very efficient as it happens not only by radiation and convection as in conventional boilers, but also by the continuous impact of the hot particles in the bed. The rate of heat transfer in atmospheric fluid beds (AFBC) could thus increased by a factor five as compared with conventional heat exchangers, this allows a more compact installation
- For the case of high excess air levels heat can be removed as sensible heat from the exhaust gases. This system is used in pressurized fluid beds (PFBC) where the pressurized hot flue gas may be used to fire a gas turbine for power generation. Heat extraction from flue gases is also used in external circulating AFBC which will be discussed below.
- Often a consistent part of the heat is extracted from ash and entrained particles; in particular for fluid beds with high excess air levels.

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The <u>advantages</u> of fluid beds as compared to conventional combustion are :

- Combustion takes place at relatively low temperatures (700-900° C). This results in low NO_x levels and less material problems (e.g. corrosion);
- More efficient heat transfer, which results in a more compact installation;
- Very efficient combustion as the contact between fuel and air is optimal;
- No or limited need for coal treatment such as pulverization;
- Low calorific fuel (e.g. biomass, wood) and waste can be burned. Combustion of waste leads to cost savings for fuel and waste disposal;
- The SO_2 content in exhaust gases can be reduced by as much as 90 % by adding limestone ($CaCO_3$) in the bed. This allows the use of high sulphur coal. The costs involved are small compared to stack gas cleaning;
- Retrofitting of conventional oil boilers with a coal fired fluid bed is possible. The fluid bed installation has lower fuel costs and typical payback times are 3-5 years.

<u>Disadvantages</u> are :

- The starting up of a fluid bed takes long time (1-4 hrs). It can be realized by preheating air which is blown through the bed or by heating the bed by oil or gas burners above the bed;
- The heat output in a conventional fluid bed can be regulated only by 25 % (turndown value 4 : 3). Much progress however is made and in the E.C. programmes several projects are carried out which try to solve this problem : by using several beds which can be slumped separately, by introducing external circulating fluid beds, by using fluid beds with a varying heat exchange surface;
- Dynamic response of the heat output for a conventional bed is slow due to the large thermal capacity of the bed. Use of external circulating fluid beds, which will be discussed below, may solve that problem;
- Large quantities of ash in particular with desulphurization;
- High energy cost of fans which blow air through the bed;
- Special feed preparation may be required for fluid bed combustion of waste;
- Investment costs are high but lower fuel costs make fluid beds already now often attractive;
- Erosion of parts in the fluid bed such as heat exchanger tubes by abrasion of inert particles; in particular at high gas velocities.

Much of the R, D and D described in this book deals with the above mentioned disadvantages : start up, turndown, dynamic response, feeding and erosion. Another important topic is circulating beds.

The study of circulating fluid beds is a fairly recent but important development; 6 of the 9 R+D projects and 3 of the 10 demonstration projects deal with this subject. The main features of circulating beds will therefore be shortly discussed. One may distinguish two cases :

For the case of low excess air and a fluid bed with a well defined bed surface an internal circulation in the bed is possible, which may be influenced by the shape of the bottom, local introduction of a stronger air flow and the shape of in bed heat exchanger. Such a circulation brings about a better fuel mixing, gives a better burnout and the temperature in the bed is homogeneous.

For the case of high excess air small particles are entrained from the bed with the flue gas. These hot particles are separated from the flue gas by a cyclone and reintroduced in the bed possibly after heat extraction with a heat exchanger. There is not a clear surface in this external circulating fluid bed. We have now a lower part which contains the heavier particles and where combustion takes place and the upper part with entrained particles. This fast circulating bed has the following advantages

- By regulating the particle flow the heat output can be regulated down to 15 % of the maximum heat output.
- By placing the heat exchangers in the upper part of the fluid bed the heat transfer and combustion part can be separated.
- Fuel treatment is not required because both small and large pieces are completely burned.
- High gas speeds give a higher heat transfer (but more erosion), which leads to a more compact installation.
- The temperature in the bed is homogeneous.

Large installations are mainly used for the production of power. For cogeneration or power production by fluid beds in future, pressurized fluid bed combustors seem to have the best chances. Atmospheric fluid bed combustors are mostly used when lower heat outputs are required. Here combustion of waste material is an application. Retrofitting of fluid beds in conventionally fired boilers is possible.

The excellent heat transfer properties of fluid beds make them very efficient heat exchangers. The development of fluid bed heat exchangers is carried out in several E.C. R+D projects.

Finally it should be clear that fluid bed combustion will not lead to energy saving as compared to conventional coal combustion (with a possible exception for sophisticated PFB units). Consumption of electricity by the fan may in fact increase the energy requirements somewhat. Fluidized bed combustion however does allow users to switch from scarse premium fuels such as oil and gas to more abundant fuels such as coal. It can also burn waste materials quite efficiently.

R + D ON FLUIDIZED BED COMBUSTORS AND HEAT EXCHANGERS CARRIED OUT IN THE FRAMEWORK OF THE COMMUNITY'S ENERGY R + D PROGRAMME

Research on fluid beds in the E.C. energy R+D Programme is carried out on five fluid bed combustors and four fluid bed heat exchangers (See table 1). Fluid bed combustor research is exclusively done on atmospheric fluid beds. Interesting work is carried out on a 25 kW internal circulating AFBC for small commercial and domestic applications. Design concepts are being tested for a double gasifier/combustor fluid bed producing hot gas at 1250° C and a conventional fluid bed producing dust free hot gas of 600° C. Furtheron an external and an internal circulating fluid bed are being developed.

For the fluid bed heat exchangers two projects deal with heat exchangers in a fluid bed and two projects investigate fluid bed gas-gas and gas-water heat exchangers.

Fluid bed combustors

In view of the large potential for small scale solid fuel boilers, the NATIONAL INSTITUTE FOR HIGHER EDUCATION, Ireland is developing a 25 kW atmospheric fluid bed combustor (AFBC) which is meant for domestic and small scale industrial and commercial applications. The AFBC will be cheap, will have a high turndown ratio (50 : 1), a short start up time (20 minutes) and will be fully automatic. Within the fluid bed (bed area 10 x 20 cm) an internal circulation is brought about by a sloped bottom and a locally stronger air flow in the upper sloping part of the bottom. Such a circulation brings about an efficient mixing and combustion of fuel with a varying diameter. The heat is extracted by fluid bed walls which are water cooled. The high turndown value can be obtained by varying the height of the bed thus varying the heat transfer surface and by partially slumping the bed; which is enabled by the sloped bottom. The start up heating is done electrically with a heater of 1 kW. The AFBC will be operational in May 1983.

Production of hot gas for drying purposes represents a significant use of energy in the E.C. countries. Presently coal fired fluid beds are already being used commercially for hot gas applications up to 950° C where contamination by ash is acceptable. The NATIONAL COAL BOARD, U.K. is experimentally evaluating design concepts for fluid beds which are able to produce a) hot air containing ash at 1250° C and b) dust free gas at 600° C.

a) In a test installation of 400 kW the concept design for a fluid bed producing flue gas at 1250° C is experimentally tested. It consists of two adjacent fluid beds, the first being operated as a partial gasifier producing low c.v. gas which is burned in the oxygen containing off-gas from the second bed. The second bed is fueled by the char from the incomplete gasification of the first bed and is operated with a high excess air level as a conventional fluid bed. Preliminary tests obtained 1200° C, further experiments should demonstrate the stable operation of this system under a range of test conditions.

b) The concept for the production of hot, dust free gas at 600° C was tested in a 200 kW unit. Air is heated by passing it through heat exchanger tubes in and above the fluid bed. The mullite tubes used in the in-bed heat exchanger broke down several times. A study suggested to use silicon carbide tubes which during 1000 hrs of testing have proved to be satisfactory. Also the second phase of the project, the design for a full size 1,8 MW installation for a malting factory, has been completed.

A further development of a fast external circulating fluid bed for production of steam is carried out by STEINMULLER, Germany. The advantages of such a circulating bed have been described previously. The main emphasis in this project is low fuel treatment (possible as in this type of fluid bed both small and large pieces are burned efficiently) and a good burn out which is ensured by the longer and effective mixing in the bed. The pilot unit has a capacity of 1 MW, will contain desulphurization facilities, will produce steam of 450° C and 20 bar and will be fired with coal and low grade fuels. The plant was to become operational in December 1982.

The fluidized bed combustion of refuse derived fuel (RDF) and industrial waste is being tested by STONE FLUIDFIRE, U.K. in a 300 kW fluid bed installation with an internal circulation of the bed induced by the sloped profile of the bottom. This circulation ensures a good mixing of the fuel and a good burn out. It is important to introduce the fuel in the central down region so that the fuel is entrained and stays a maximum time within the bed before it reaches the surface. Still a high proportion of the volatile hydrocarbons is released so fast, that it is burned above the bed resulting in a high CO content (0,5 %). In order to avoid this, air is also introduced above the bed. For the raw RDF a special pneumatic feed system had to be developed. Waste generally has a low calorific value and may be wet. Addition of coal or propane is therefore necessary. It was possible to sustain combustion with 60 % of the heat input provided by waste residue. The installation has a efficiency of 80 % if pelletized fuel (RDF) is used and started testing in January 1982.

Fluid bed heat exchangers

In the R+D programme on fluid bed heat exchangers different types of heat exchangers are being investigated. Two projects study heat exchangers in fluid bed combustors. Two other projects investigate a gas-gas heat exchanger and a gas-water heat exchanger based on the fluid bed concept with the inert particles as a heat exchange medium.