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FLUIDIZED-BED GASIFICATION AND SLAGGING COMBUSTION SYSTEM

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ABSTRACT

In Japan, the main form of waste treatment used to be by combustion using an incinerator. In recent years, however, gasification system has been developed in an attempt to meet the need for controlling dioxins and detoxifying ash. A total of 30 companies, some of which are engaged in their own process development on the basis of their proprietary technologies and some of which will rely on foreign technology for their development efforts, are competing with each other to develop this technology. It should be remembered that Japan with its confined territory is under extreme pressure to find landfill sites for waste disposal. It is therefore easy to understand how pressing the need for a treatment system making little claim on landfill capacity is.

The authors have developed and commercialized the fluidized-bed gasification and slag combustion system as an advanced waste treatment technology on the basis of the fluidized bed know-how accumulated over a long period. The system is not a simple treatment process but represents a chemical recycling technology in which the wastes themselves play the role of an important raw material. Research is also underway to develop high-efficiency power generating and incineration-less power generating systems. With their lower impact on the environment, these technologies will make a significant contribution to 21st century civilization.

This article presents first the fluidized-bed gasification and slag combustion system as the core technology developed by the authors and then describes the evolution techniques developed and commercialized on the basis of this core technology.

THE EVOLUTIONARY PROCESS OF EBARA‘S FLUIDIZED BED TECHNOLOGY

Fig. 1 traces the evolutionary path along which Ebara’s fluidized bed technology has evolved. Each of these development stages is briefly outlined below.

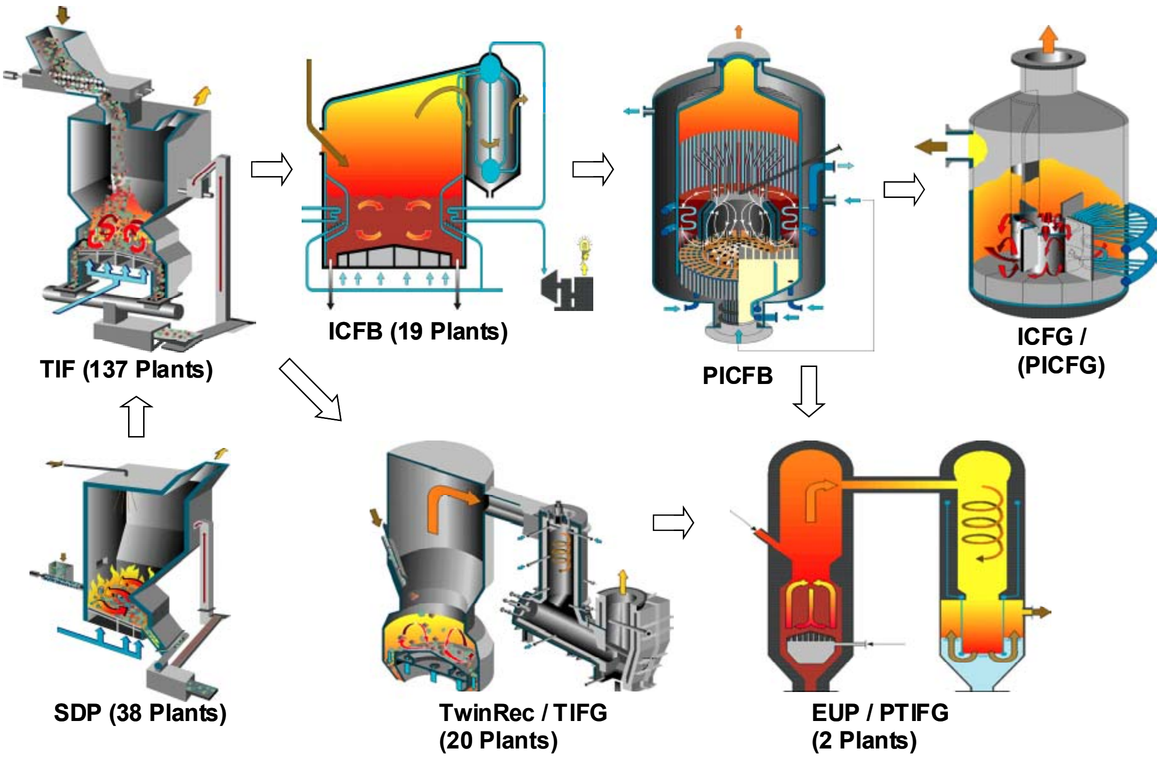

Fig. 1 The evolutionary path of Ebara's fluidized bed technology

Sterile Disposal Plant (SDP)

The acquisition of a British patent in 1974 marked the beginning of Ebara's commitment to fluidized bed technology development. Despite the considerable initial difficulties, we have been successful in the development mainly of small systems and are still active in this area. At present there are 38 units in operation or under constructions.

Twin-internally Circulating Fluidized Bed Furnace (TIF)

The ordinary fluidized bed incinerators had required the previous crushing and disintegration of the waste materials. This new technology was developed for the explicit purpose of incinerating municipal wastes without preliminary crushing.

In this furnace, sand as the fluidizing material revolves along the furnace walls on both sides and collects in the center of the furnace. On its descent in the furnace it is dispersed to both sides. As the sand moves sideways it is capable of accommodating a large-size waste. At present there are 137 of this mainly medium-to-large capacity type of furnace operative or under construction.

Ebara has supplied this technology to Lurgi of Germany. At present, plants of this type are in operation in Macomer (72t/d) in Italy, Madrid (660t/d) in Spain, Berlin (200t/d) in Germany, and Gien (240t/d) in France and in the process of being built in Moscow (990t/d) in Russia and Mulhouse (560t/d) in France.

While practically all of Japanese combustion technology is imported through technology transfer from abroad, this technology has been created in Japan and marks Japan's first contribution to technology overseas in the combustion technology field.

Internally Circulating Fluidized-Bed Boiler (ICFB)

In general, the bubbling type fluidized bed boiler is equipped with bed-immersed heat transfer tubes in the combustion chamber. It has therefore been difficult to control load variation and the wear of the bed-immersed heat tubes has posed a serious problem. This technology inherits the advantageous features for the TIF's combustion chamber and permit the effective control of the total heat transfer coefficient with the use of heat recovery chambers installed on either side. As a result, it is possible to combust any combustible material from municipal wastes to coal and to control both the bed temperature and load changes with total freedom.

At present, there are 19 of these boilers in operation or under construction. They are designed primarily for high-calorific wastes and coal. This technology has also been transferred to Lurgi of Germany (November 1998).

Pressurized ICFB (PICFB)

This pressurized fluidized bed system applies pressure to the above ICFB and is chiefly used for co-generation using coal as the fuel. This technology was developed on the basis of a development project subsidized under the Coal Utilization Technology Promotion Scheme of the Resources and Energy Agency of the Ministry of International Trade and Industry (MITI). The research work was conducted on the 4MWth pilot plant in collaboration with the Center for Coal Utilization, JAPAN (CCUJ). The results of this development work led to the PTIFG and PICFG that are described below.

TIF Gasifier (TIFG)

This technology uses a cylindrical version of the above TIF as a gasifier. It is capable of gasifying wastes and utilizing the heat of the gases to generate high temperatures in the next stage slag combustion system. In this high-temperature second system, dioxins are decomposed and the ash is converted to a molten slag by using the heat in the system. Details of this technology are presented in Section 2.

This technology has been supplied to ABB ALSTOM POWER (November 1998).

Pressurized TIFG (PTIFG)

This system is a two-stage pressurized gasifier and slag combustion system. The first-stage gasifier uses the above TIFG as a pressurized low-temperature gasifier and the second-stage is a high-temperature gasifier. The system is capable of recovering the chemicals feedstock materials generated from the wastes such as hydrogen and ammonia. Details of this technology are discussed in Section 3.

Pressurized Internally Circulating Fluidized-bed Gasifier (PICFG)

This technology takes the above PICFB a step further by providing it with a gasification chamber. The PICFG is the “ultimate furnace” in that a single furnace accommodates three different functions, namely, gasification, char combustion and bed temperature control. As it inherits the perfected PICFB technology, there are few technical barriers to its acceptance as a technology that will contribute to CO2 reduction in the future. This technology is described in fuller details in Section 4.

THE TWIN INTERNALLY CIRCULATING FLUIDIZED-BED GASIFIER (TIFG)

At present, there are 30 Japanese companies credited with being engaged in the development of gasifier and slag combustion systems, and the system can be divided into three main types: 1) the shaft type that slags the entire amount directly, 2) the fluidized bed type that gasifies the wastes directly with slagging, and 3) the kiln type that gasified the wastes indirectly with slagging. 13 companies pursue research on the fluidized bed system.

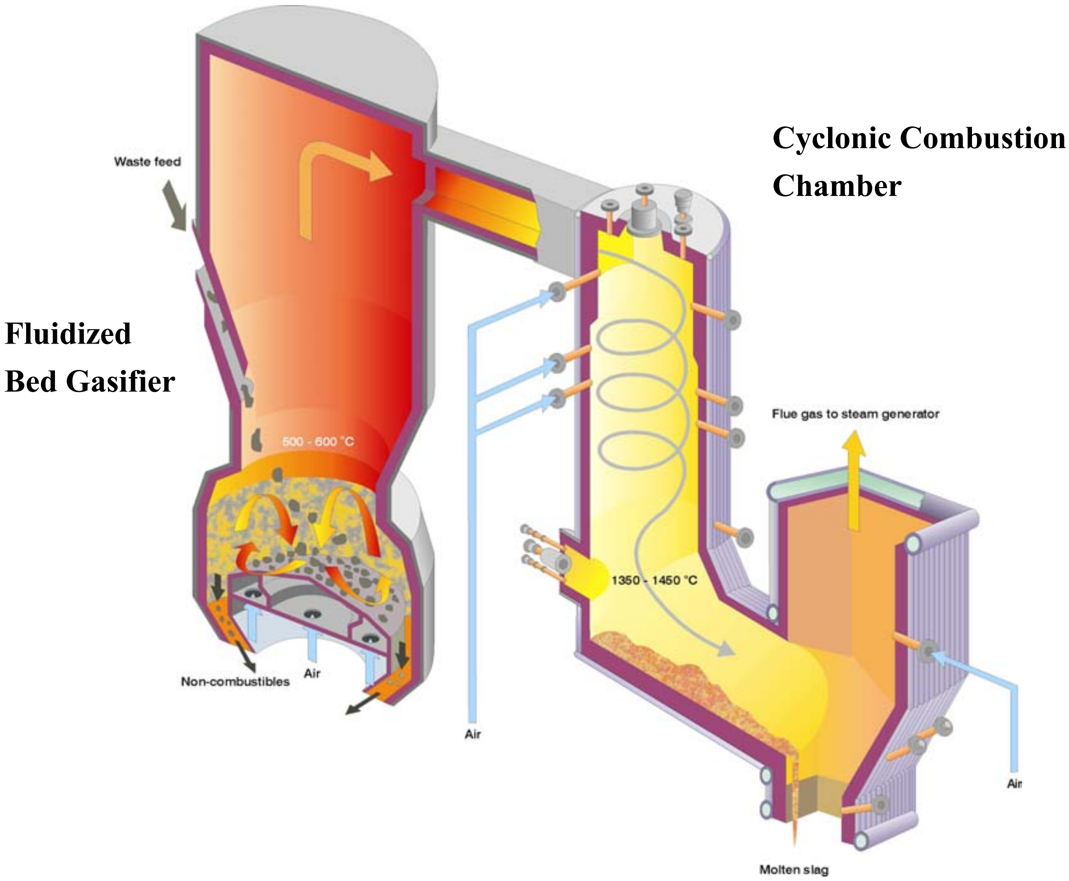

Fig2 Structure of the Twin internally Circulating Fluidized-bed Gasifier (TIFG)

The Ebara system uses a cylindrical version of its well-established revolving type fluidized bed incinerator as the gasifier. This system gasified the wastes first and uses the heat content of the gases to raise the temperature in the next-stage slag combustion furnace. Because of the high temperatures, dioxins are decomposed and the ash is converted to a slag under its own heat [1]. Fig. 2 shows the structure of the system (called TIFG for short).

Table 1 shows the level of orders Ebara has received for this system. At present, there are two systems (number of furnaces: 3) under construction for industrial waste treatment and five systems (number of furnaces: 12) for municipal waste treatment. The No. 1 unit currently in operation is Japan's largest gasification and slagging combustion system with a capacity of 450t/d.

Table 1 Order Records for the Ebara Gasification and Slagging Combustion System

No.	Name of Customer	Treated Materials	Throughput	Completion	Electricity generated
1.	Aomori RER	SD, Sludge	450 t/d (225 × 2)	March 2001	17,800kW
2.	Joetsu Wide-range regional Union	Plastic wastes, night soil sludge	15.7 t/d	March 2000	---
3.	Sakata Local Clean Union	Municipal wastes	196 t/d (98 × 2)	March 2002	1,990kW
4.	Nikko Mikkaichi Recycling	Plastic wastes, copper dross	70 t/d	January 2001	---
5.	Kawaguchi City	Municipal wastes, + Ashes from other sites	420 t/d (140 × 3)	November 2002	11,700kW
6.	Ube City	Municipal wastes	198 t/d (99 × 2)	November 2002	4,100kW
7.	Chuno Wide-range regional Union	Municipal wastes	168 t/d (56 × 3)	March 2003	1,980kW
8.	Minami-Shishu Wide-range regional Union	Municipal wastes	168 t/d (56 × 3)	March 2003	---

Thermal Recycling

Until now, power generation from wastes has a low efficiency because the temperature of the superheated steam could not be increased to a high level due to the corrosion problems this would have caused. When waste is converted RDF its impurities are removed, its moisture eliminated by drying, and the waste quality unified. As a result, stable combustion conditions are achieved (and operation at a low air ratio is possible) while the synthesis of dioxins is suppressed. Because the RDF has the same composition as the original waste material, however, there is little or no difference from mixed waste combustion in terms of the re-synthesis of dioxins. (The re-synthesis of dioxins is affected especially by the copper chloride contents in the boiler.) Further, even when the HCl concentration decreases, chlorine is not removed and it is therefore not possible avoid high-temperature molten salt corrosion. (The salt concentration has a greater effect that the HCl concentration.) The authors believe that the maximum permissible limit (including economic aspects) for the superheated steam temperature is 400 - 450 degrees C.

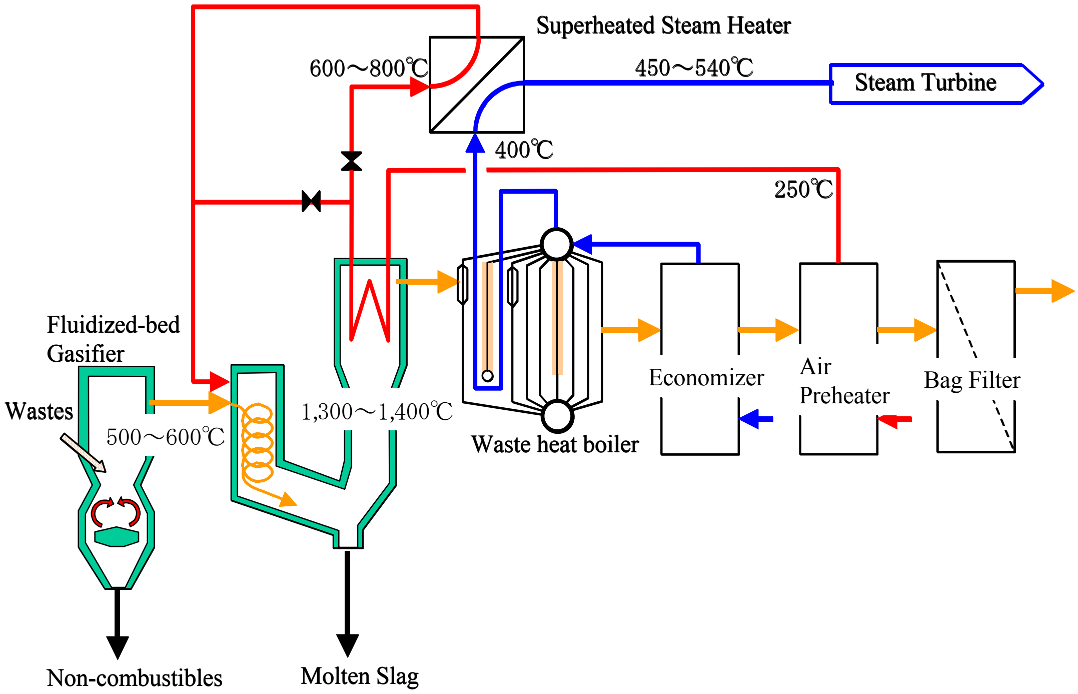

Fig.3 Schematic of the high-efficiency waste-based power generating system using indirect heating for the superheated steam

Based on a somewhat different notion, the authors are in the process of developing and verifying a system in which high-temperature air of around 700 deg. C is used as the heat carrier for indirectly heating the superheated steam from 400 deg. C to 500 deg. C or more. Fig. 3 shows a schematic of the high-efficiency waste-based power generating system using indirect heating for the superheated steam. The air that serves as the heat carrier does not require the high pressures needed for steam. As a result, the materials of the air heating tubes do not required to have strength in high-temperature condition such as boiler tubes and, instead, a suitable corrosion-resistant material (heat-resistant cast steel, ceramic, etc.) may be used.

Until the present, verification tests have been performed on a project entrusted by MITI, NEDO and the Institute of Applied Energy. This system is capable of avoiding high-temperature molten salt corrosion and of achieving a high gross and net efficiency. It should be noted that the gross efficiency varies in accordance with the size of the furnace, the nature of the waste and the steam specifications and that its target is generally in the region of 22-28% for a 100-200t/d capacity system and 28-33% for a 200t/d or greater capacity system.

CHEMICAL RECYCLING

Application of the Pressurized TIFG (PTIFG) to Chemical Recycling

The reason why chemical recycling has not taken root so far is due to economic problems and also the problems of treating rejected materials as the costs for sorting materials such as PVC were excessively high. With the enforcement of the Law on Recycling of Containers and Packaging, some headway has been made on the problem of economic viability. It is also clear that a technology that requires no sorting and not particular preliminary treatment and a technology that is also capable of converting mixed-in organic wastes to chemical feedstock materials has the prospect of becoming the ideal recycling system [2].

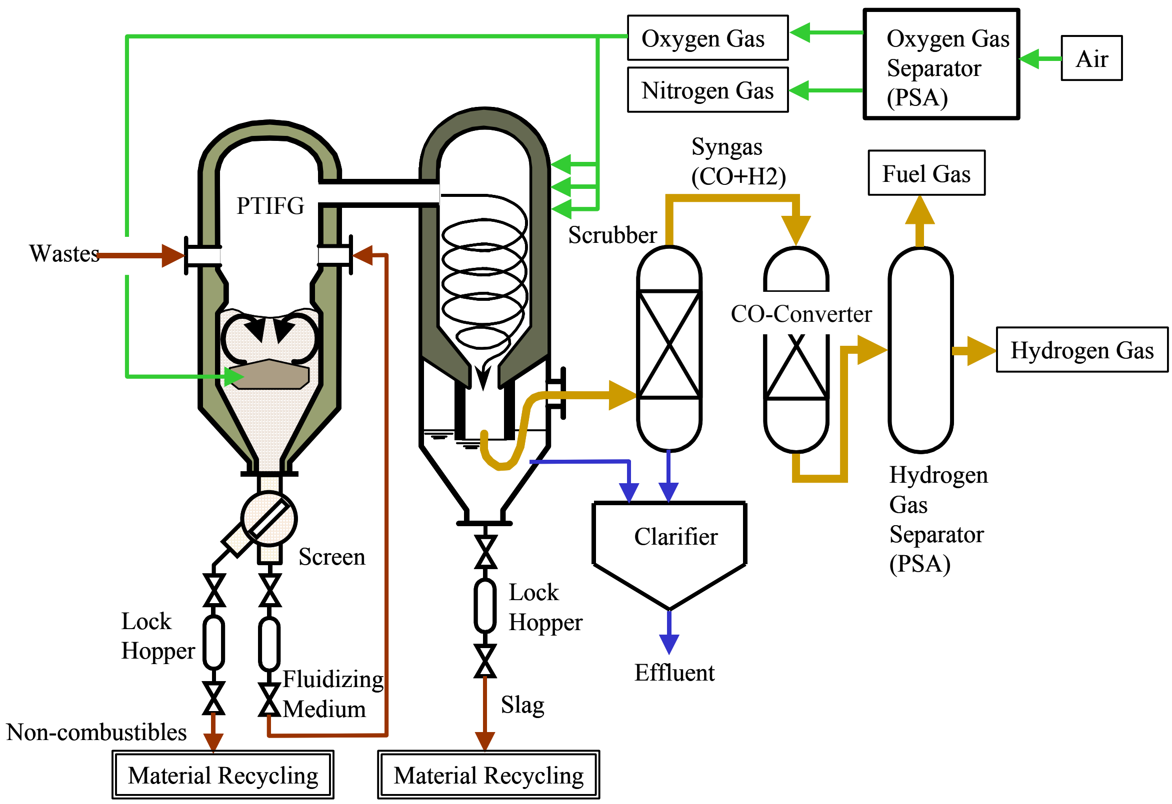

Fig.4 Chemical recycling system (Pressurized Two-Stage Gasification System)

Fig. 4 shows the chemical recycling system developed by the authors. As can be seen, this system is the two-stage pressurized gasification and slagging combustion system (abbreviated name: PTIFG), which combines a low-temperature fluidized-bed gasification furnace with a subsequent high-temperature gasification furnace, and is capable of generating syngas (a gas mixture of hydrogen and carbon monoxide) from the plastic wastes, which serves as the feedstock for the ammonia synthesis process [3]. This technology was jointly developed between Ube Industries, Ltd. and Ebara as the project entrusted by MITI/NEDO/and the Plastics Waste Management Institute. Pilot plant trial operation was initiated in

February 2000. Operation to recycle plastic wastes in accordance with the Law of Recycling of Containers and Packaging was started in December 2000 (as a joint project between Ube Industries, Ltd. and Ebara).

The technology can be directly applied to co-generation and to liquid fuel production, including methanol and can thus make a significant contribution to CO2 reduction and for automobile fuel as a 21st century recycling technology. In 2001, some of the syngas generated from wastes is scheduled to be supplied to the existing ammonia synthesis plant of Ube Ammonia Industry for use as a feedstock for ammonia synthesis.

Application to normal pressure systems (Non-incineration power generating system)

The non-combustion systems developed by the authors generate syngas from wastes and generate electricity from these gases in Fuel Cells. The objective of this system is to "get away from incineration" and "come as close to detoxification as possible". "Near-perfect detoxification" is achieved thanks to the waste gas scrubbing effect of the wet process used for the refining of the syngas. It basic structure comes very close to the two-stage pressurized gasification system. To make the system easier for the operator, a system is being developed that uses normal pressure instead of the application of elevated pressures and that can also cope with municipal wastes with a low calorific value. When this technology is completed, the result will be small-dispersed power plants that come very close to being totally non-toxic. This will favor a zero-emission approach, with no major energy - including electricity - being spent on waste treatment. In the case of low-calorific wastes there will be a low cold gas efficiency and electric power will be generated only to the extent necessary to meet the plant's own power requirement. This system is therefore suited for facilities of a capacity scale of around 100t/d, which did not produce electricity in the past. It is also possible to generate electricity using gas turbines or gas engines although this is somewhat different from the incineration-free-idea. Non-incineration gas engine type power generating systems are referred to as TIFG-GE for short. Trial operation of a small experimental plant using this technology has been carried out since January 2001.

MULTI-FUEL/MULTI-PRODUCT INTERNALLY CIRCULATING FLUIDIZED-BED GASIFIER (PICFG)

The internally circulating fluidized-bed gasifier is characterized in that a single furnace accommodates three different functions, namely, gasification, char combustion and bed temperature control. Fig. 5 shows the principle of this system. The objective of this furnace is not only to gasify wastes but also a great diversity of fuels (multi-fuel function) available throughout the world such as coal, biomass or wastes. For this purpose, a char combustor is installed by allowing for the ability to reinforce or control the selective combustion of char. In addition, it's applications cover a large variety of possible uses (multi-product capability) from high-efficiency power generation to chemical feedstock synthesis. So this system has a potential not only for reducing CO2 emissions but also contributing to future energy security. When used for power generation (abbreviated name: PICFG-GT) it is possible to achieve a gross efficiency of 51% or more and a net efficiency of 48% or more. By replacing the existing coal-fired thermal power plant with this system, it is thus possible to achieve a nearly 30% CO2 reduction. It also helps save fossil fuels. According to the desired application, the system can either be a normal pressure (abbreviated name: ICFG) or a pressurized system (abbreviated name: PICFG).

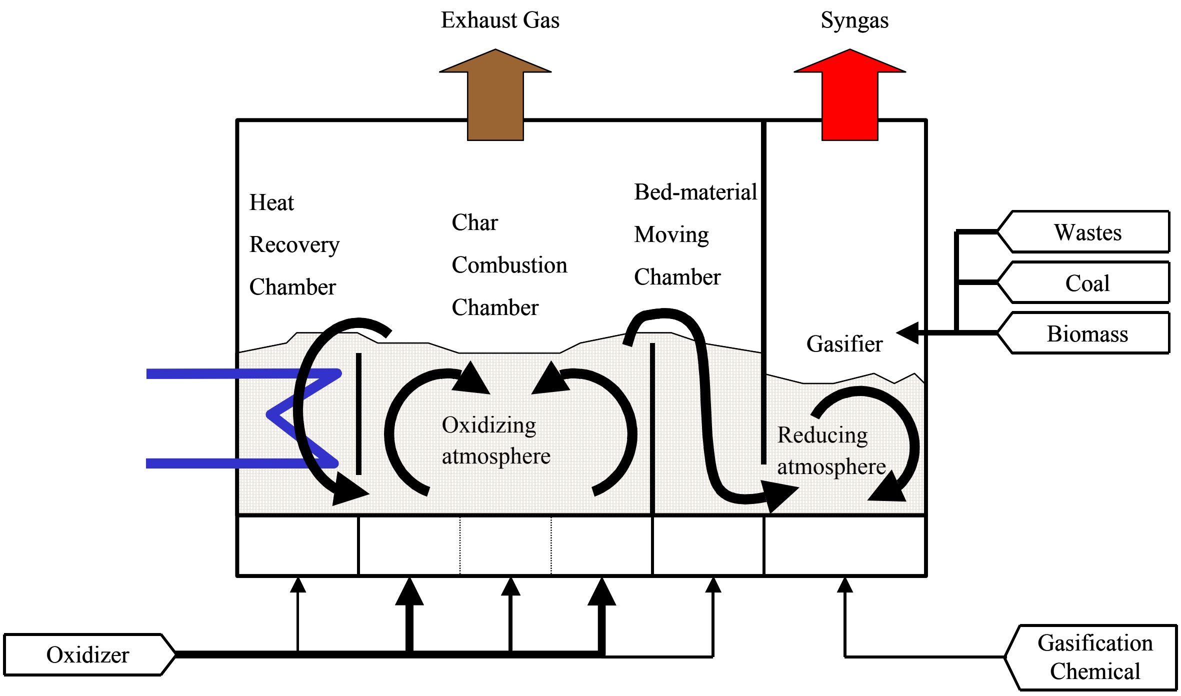

Fig.5 Principle of the internally circulating fluidized-bed gasifier

At present, joint research and development is underway with the Chubu Electric Power Company on coal gasification using this technology. Ebara has also been awarded a "Subsidy Fund for Industrial Technology Development and Commercialization" from NEDO. Experiments on the gasification of biomass are due to start in December 2000. Normal pressure experiments are planned for fiscal 2000 and experiments under elevated pressure in fiscal 2001.

CONCLUSIONS

To address the problems of the environment it is important to continue technology development by constantly being aware of the energy issues and the need for life cycle assessment (LCA). The authors have introduced here five technologies that have been or are still being development and it is hoped that this article may make some contribution to the development of technology with a smaller environmental impact. Our thanks are due to Professor Horio of the Tokyo University of Agriculture and Technology for his generous suggestions on some of the developments related to fluidizing bed technology.

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