INITIATION AND DEVELOPMENT OF FLUIDIZED-BED BOILERS FOR OIL SHALE IN CHINA

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ABSTRACT

China is rich in oil shale resources. According to the estimation, the prospective reserves of oil shale are over 400 billion tons. However, since the oil content of oil shale is not high, it is not a suitable fuel for the conventional boilers. In the early 60s, China decided to develop the engineering construction of fluidized-bed combustion boiler (FBB) for burning low grade fuel. After efforts being made, a fully fluidized industrial boiler was constructed in 1965 with a throughput of 300 tons oil shale fines per day (particle size: 0-10mm) and an evaporation rate of 14.5 tons per hour. The production record of 50,000h continuous and stable operation was achieved, thus laying a foundation for utilizing low grade fuel in boilers. Under the guidance of the chemical engineering study on fluidization carried out by scientific research institutions and universities, mor than 2000 FBB of diversified process models have been developed and the scaling up tests are underway in the enterprises concerned. The authors think that as the reserves of oil shale and other fossil fuels of low heating value are about several times higher than that of oil and natural gas in the world, they are an important pillar of the future energy and building material industries. Many countries in the world used to pay attention to the development of FBB when the world was faced with an energy crisis. However, the development was stagnated when the oil price was steeply reduced. At present, as the progress of world modernization is being speeded up and the energy supply is getting shorter and shorter, it can be predicted that in the near future, the FBB for burning low grade fuel is sure to be brought into line again with the programme of engineering construction in various countries of the world, which will be given the first priority to develop.

China has abundant oil shale resources which are widely distributed and mostly are of low grade, 5-7% or less. Although the systematic geological work on this specific subject has not been carried out, according to the estimation on reserves of both developed and discovered mining areas, the prospective reserves of oil shale are over 400 billion tons. Additionally, China has large quantities of high ash combustible minerals: coal slimes, stone-like coal and coal refuse, etc., about 70 million tons a year. The amount of coal refuse accumulated over many years is about 1 billion tons. It is impossible or very difficult to use the above-mentioned high ash combustible ore fuels in the existing conventional boilers. Even if they are used with difficulty by mixing with high quality fuel, there must be unfavourable factors brought about, such as difficulty in starting up, unstable combustion, sharp reduction in boiler efficiency and great trouble in operation, which will eventually lead to failure at the end. On the contrary, all of these low grade combustible minerals are the most suitable fuels for FBB. Since the thermal capacity of fluidized bed is high, the residence time of fuel in the bed is long and hot particles of high frequency and high temperature in the bed colliding each other frequently, fuels of low heating value and high moisture can quickly reach the combustion temperature and start to burn. At the same time, the random back-mixing movement of particles make them contact fully with combustion air so as to meet the requirements of continuous, stable and full combustion.

It is generally considered that FBB has the flollowing outstanding advantages: (1) Since the thermal capacity of fluidized bed is high, hot particles of high frequency collide each other frequently by the random movement and the residence time is long, any combustible substances, including low grade fuel with heating value as low as 800 kcal/kg and moisture content as high as 70%, can be burnt and meet the requirement of stable combustion. (2) The fluidized bed temperature can be controlled within the range of 750-810°C. At this temperature range, ash is unlikely to be softened or vitrificated so that it can be used in the making of building materials or as the effective admixture for building materials. Thus, the high ash combustible substances can be fully converted to useful

commodities. (3) Since the combustion process of fluidized bed is mainly completed in bed, the large volume combustion chamber is not necessary. Therefore, the volume of FBB with the same function is only 1/6 - 1/10 of that of the conventional boilers and the volume of pressurized fluidized boiler and multi-bed fluidized boiler is even smaller, only 1/20 of that of the conventional boilers. (4) Since the combustion of fluidized bed is mainly completed in bed, no black smoke comes out from the stack, the bed temperature is relatively low, excess air coefficient is high and NO_x emission is low. For high sulfur coal, limestone bed can be used to reduce SO_2 by 90%. Thus, air pollution is much smaller than that of conventional boilers. (5) The immersed tube in the bed is a process of solid heat transfer. The heat transfer coefficient can be as high as 240 kcal/m²/°C, about 4-5 times higher than that of the conventional boilers, which is only 50 kcal/m²/°C in general. (6) Since FBB uses <10 mm fully fluidized particles as fuel, no grinding is necessary and energy consumption and mechanical errosion can thus be reduced. (7) The problems of uneven air distribution and tube errosion of high power boilers can be solved by improving the distribution of air, the design of boiler tubes arrangement and the selection of appropriate steel materials.

Owing to the above-mentioned outstanding advantages of FBB and the power requirement of oil shale enterprises, the Ministry of Petroleum Industry of China decided to develop, design and construct FBB. The collection of relevant information started in the early 60s and technicians were sent to Europe in 1963 to investigate this technology. Some engineers (with Mr. Shi Guoquan, Mr. Chen Yizhou, Mr. Luo Rongtao and Mr. Wang Huiming as the main force) of Fushun Petroleum Design Institute and Maoming Petroleum Industrial Company were organized to start research, experimental and engineering design work on FBB. Under the leadership and support of Maoming Petroleum Industrial Company and after two years' hard work of staff and workers concerned, the first FBB burning low grade fuel was constructed in Maoming Oil Shale Refinery. The throughput of granular oil shale refuse was 300 tons/day and the steam evaporation rate was 14.5 tons/hr. This boiler was continuously operated for 50,000 hours and its ash residue could be used as feedstock of clinker-free cement or cement admixture. In 1966, this FBB passed the Ministrial

appraisal and a meeting was held for urging on its popularization; thus, a new way was opened up for the utilization of oil shale and other low grade fuels in steam boilers in China.

The structural diagram and the main parameters of Maoming 14.5 t/h FBB are shown in the paper "Fluid-bed boiler burning particulate Maoming oil shale" and the relationship between the combustion temperature of shale ash and compressive strength is shown in the paper "Investigation on the portland possolana cement with more shale ash content" in this Proceedings respectively.

Since then, more than 1000 units of medium and small FBB of various types have been developed by universities and organizations concerned, such as Qinhua University, Zhejiang University and Shanghai Boiler Research Institute through deep-going research and modification. Fuels, including oil shale of low heating value, high ash stone-like coal and coal refuse, etc., can all burn in FBB stably. In addition, the chemical engineering study on fluidization made by Shangxi Research Institute of Coal Chemistry and Metallurgical Chemical Research Institute of China Academy of Science, etc. have provided the guidance and support in theoretical aspect of FBB. The scaling up and development of FBB are underway successively in oil shale enterprises, coal enterprises and other industrial enterprises of China according to their needs and investmental capability. During the process of each scaling up, some new problems are revealed and new beneficial experiences are accumulated. The Chinese government has paid great attention to the development of FBB and the research projects were made for tackling in a hope of achieving satisfactory results for its wide-spread applications.

In the aspect of academic research and engineering development of FBB at home and abroad, in the recent two decades years, unceasing progress has been made along with the development of the academic research on fluidization. At various sessions of "Conference on Fluidization", "Sino-Japanese Symposium on Fluidization" and "International Fluidized-bed Combustion and Applied Technology Symposium", the Chinese and foreign scientists presented many papers concerning the basic study and applied technology of fluidized bed combustion. Prof. Zhao Zongyu presented one paper in 1963 on "Report on the investigation of power generating units

for burning oil shale of low heating value in the Federal Republic of Germany" and one paper in 1973 on "Progress of Industrial Application of Fluidization Technology" at the first symposium on fluidization in China to overview the development of fluidization technology in fluidized-bed combustion technology at home and abroad.

As to the development of engineering technology of fluidized bed combustion, the Chinese condition has been briefly introduced above. At abroad, it is reported that in the recent 10 to 20 years, considerable development has been made. The technology of atmospheric fluidized boiler (AFB) has been developed from the small and medium scale to commercial scale of steam boilers. Lurgi Company, BBC Company and Fosterwheeler Corporation all claimed that they could provide large industrial development units and technology as well as full commercial guanrantee. In the aspect of pressurized fluidized bed boilers (PFB), remarkable progress has been reported, but no specific report on its commercialization is seen yet. Foster wheeler Corporation reported its multi-bed fluidized bed boiler which was used with 150,000 kw unit on trial and also put forward its tentative idea for the combined process of "High temperature pyrolysis of coal and fluidized bed combustion of hot coke residue" at the International Fluidized Bed Combustion Symposium held in Beijing in 1983. UK also reported their plans of developing fluidized bed boilers for 20,000, 120,000 and 660,000 kw power stations and perspective plan of achieving steam generation rate of 2020 t/h. At that time, they thought the large scale power station would possibly use FBB in the early 70s. PER Company in the US used to organize the work on designing FBB of large volume (to coordinate with the design of modular boilers for 300,000 kw and 1,200,000 kw power generating sets). It is said the reserves of coal in the US is about 60-80 times higher than the total reserves of oil, natural gas and fission uranium. Therefore, the development of FBB should be given the first priority. These plans and tentative ideas might have been given up under the conditions of reduction in oil price and shortage in investment. In addition, the FBB developed in the USSR and France belong to "semi-fluidized" or "suspended combustion" boilers, suitable for high grade fuel.

In general, the world is rich in oil shale resources. It is estimated that the potential reserves of oil from oil shale and oil sand are up to 2,000,000 x 10^9 barrels. Plus ore fuels of low heating value such as high ash coal, high moisture peat, stone-like coal and coal refuse, the reserves would be even larger. These are all the optimal fuels for FBB. Through fluidized bed combustion, not only the thermal energy can be fully utilized, but also the tremendous amount of ash can be converted to highly active and good quality building materials. Moreover, the toxic components, such as S, N, can be converted to important chemical feedstock. Therefore, the economic and environment efficiencies of fluidized bed combustion are obviously high. During the period of energy crisis, many countries gave the first priority of development to the FBB for burning low grade fuels. But the development was stagnated when oil price was reduced. In the future, the progress of modernization construction of the world will be speeded up continuously and the energy demand will increase sharply. Thus, the problem of short supply of energy is inevitably getting serious with each passing day. It can be predicted that the FBB for burning low grade fuel will certainly be taken again in various countries as the project which will be given the first priority to develop.

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