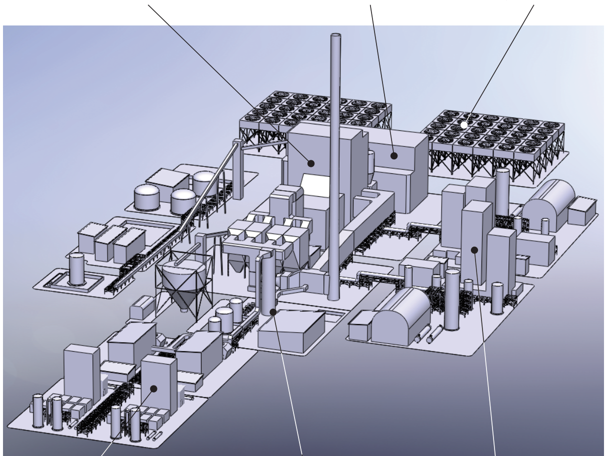
A Big Step toward Zero Emission Power Plants

CO_2 capture system using oxyfuel technology for coal-fired power plants

The emission of CO_2, which is said to be one of the main causes of drastic climate change, has continued to increase. We have continuously been engaged in research and development over the years to accomplish the goal of effectively reducing the emissions of environmental pollutants from coal-fired power plants to zero.
Having completed the demonstration in Callide (Australia), the oxyfuel technology is now moving on to the next step.

Callide Power Plant, Australia (30 MWe-class)

500 MWe-class plant



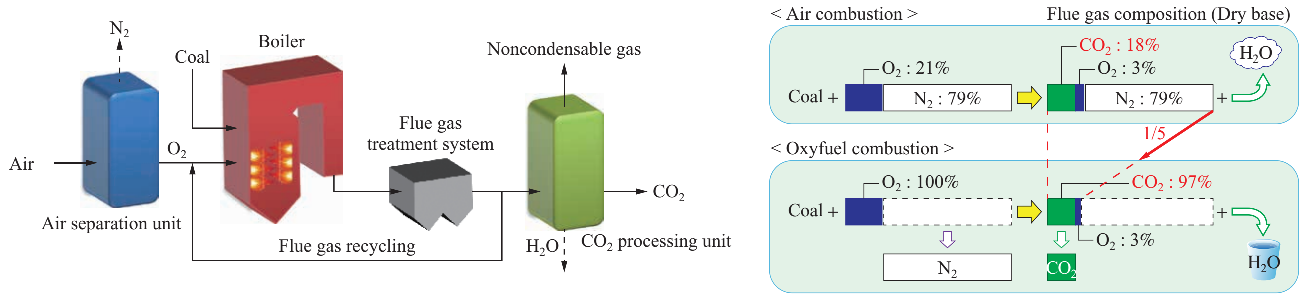
Scale-up image of power plant with oxyfuel technology

CO_2 emission control and securing stable power sources

The emission of CO_2, which is said to be one of the main causes of drastic climate change, has continued to increase. In March 2015, the global monthly average value of atmospheric CO_2 concentration reached to 400 ppm. It is reported that the atmospheric CO_2 concentration must be kept under 450 ppm in order for the global average temperature to remain two degrees Celsius higher than it was before the Industrial Revolution. It is necessary to significantly reduce the amount of CO_2 emission in the coming 10 to 20 years to achieve that goal. In recent years, laws and regulations have been developed toward the promotion of CO_2 emission control. Many countries make efforts to reduce CO_2 emissions based on Paris Agreement.

Coal is a stable and abundant primary energy resource for power generation around the world. The percentage of coal-fired power generation among all forms of electricity generation is relatively high, making coal a major source of electricity.

On the other hand, the issue on coal-fired power plants is CO_2 emissions to atmosphere by burning coal. Therefore, large amount of CO_2 capture and storage from coal-fired power plant is urgent mission. Carbon dioxide Capture and Storage (CCS) technology is being developed as one of the efforts to resolve it. CCS technology already reaches to the commercial stage worldwide and it has begun to be constructed



Left: CO_2 capture process by oxyfuel technology,
Right: Difference in flue gas composition between air combustion and oxyfuel combustion

and put into commercial operation in large-scale power plants. At the moment, the spread of CCS technology is gathering momentum.

CO_2 capture system with oxyfuel

Oxyfuel is a technology in which fossil fuels like coal are burned with oxygen (O_2) separated from air using an Air Separation Unit (ASU). By combusting fuel with oxygen, the flue gas is mainly composed of CO_2 and H_2O and the CO_2 ratio in the flue gas can theoretically be increased up to 90 dry% or higher. CO_2 capture system by oxygen combustion is a method of capturing CO_2 by removing water, oxygen, and other contaminants from flue gases in the CO_2 capture process. Captured CO_2 is pressurized and injected into underground storage layers in storage sites.

Oxyfuel boiler system is the technology based on a combination of existing technologies and equipment. It can be a new installation or it can be adapted to existing air combustion power plants. In addition, when the technology is adapted for installation in an existing plant, there is no need to modify boiler pressure parts and steam turbines. As it utilizes the equipment design techniques of existing air combustion boilers to secure heat transfer performance equivalent to air combustion, recycled flue gases are mixed with the oxygen and burned. Furthermore, when new boilers designed especially for oxyfuel are installed in the future, it should be possible to reduce the amount of recirculated gases and to make the boilers smaller.

Oxyfuel systems have several features as described below. There is no need to separate low-concentration CO_2 as in the case of the flue gases of air combustion. Furthermore, as the amount of total emission gases is about five times smaller than that of air combustion, the gas treatment system of the CO_2 capture process can be much smaller. On the other hand, there are several issues to consider such as the fact that flue gases have high CO_2 concentration, that water content and corrosive gas content are concentrated, and that flue gases are recovered. In order to deal with such issues, the following matters must be considered in the design of boilers and their systems.

(1) Ascertaining combustion and heat transfer characteristics of the boiler process, attaining adequate CO_2 concentration and performance, developing a control method specific to oxyfuel, and reliability in long-term operation

(2) Developing an operation method in oxyfuel mode considering stable operation of plants, switching methods between oxyfuel running mode and air combustion running mode, operation in case of emergency stop, safe handling of oxygen, etc.

(3) Removal of contaminants from flue gases generated by oxyfuel suitable for transport, storage, and utilization and development of process to capture high-purity CO_2

(4) Consideration of low-temperature corrosion due to concentration of corrosive gases and H_2O

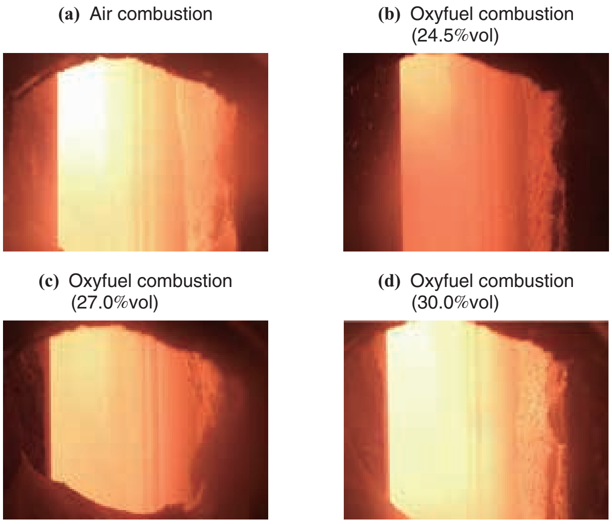
Callide Oxyfuel Project

IHI has conducted fundamental research, combustion tests, and operability studies since 1989, acquiring the techniques needed to apply oxyfuel technology to an actual coal-fired power plant. As a result, we conducted a demonstration project on the integrated processes involved in CO_2 capture technology and applied oxyfuel technology to a coal-fired power plant in Queensland, Australia. It was the first attempt in the world to verify that an existing power plant that had been operating commercially could be retrofitted into a CO_2 capture type oxyfuel plant.

The Callide Oxyfuel Project started in 2008. Australian and Japanese companies participated in the project with the support of the Australian and Japanese governments. This project was carried out in two stages: 1 CO_2 capture from oxyfuel combustion in the power plant, and 2 the transport of CO_2 captured from the power plant and its injection into the ground.

The first stage began with retrofit work and commissioning. Demonstration of oxyfuel combustion and CO_2 capturing started in December 2012 and finished in March 2015. It achieved over 10 000 hours of accumulated oxyfuel operation and over 5 500 hours of CO_2 processing unit operation. Much data concerning plant performance in oxyfuel operation and facility reliability were obtained. The main test items are described below.

(1) When oxyfuel technology is applied to an existing boiler plant, it should be operated at the performance level equivalent to the required air combustion. It was confirmed



Comparison of flames between air combustion and oxyfuel combustion (Values are boiler inlet O_2 concentration.)

that operation is automatically switched between air combustion and oxyfuel combustion. The flames of air combustion and oxyfuel combustion with different boiler inlet O_2 concentrations are shown in the photos. Although the brightness of flame is different, performance equivalent to air combustion is achieved at a certain load.

(2) Durability of mechanics in long-term operation was confirmed for both component parts of the retrofitted and existing parts.

(3) The following factors which are important for large-scale commercial plants were verified: low load operation, changes in load, controllability, plant operation in case of emergency (safe stop, rapid load reduction), and mode transition to oxyfuel under low load.

(4) The CO_2 concentration from the CO_2 Processing Unit (CPU) was nearly 100% pure. In addition, the operation performance of equipment, the removal characteristics of atmospheric pollutants in exhaust gases, and the behavior of trace elements were examined.

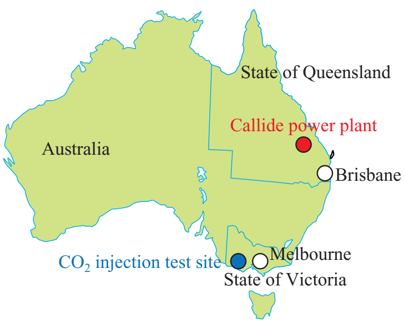
In the second stage, part of the CO_2 captured in the first stage was transported overland to the state of Victoria from October to December 2014 and was injected underground in the Otway Project Site of the CO2CRC (Cooperative Research Centre for Greenhouse Gas Technologies). The injection facility had already been constructed by CO2CRC. The injected CO_2 was used to assess its geochemical and geophysical behavior in the storage layer. This was the first time in the world that CO_2 captured from an oxyfuel boiler in a coal-fired power plant was injected into underground. This was also the first time in Australia that CO_2 captured from a thermal power plant was injected into underground. The objective of the project, a complete demonstration of total process from CO_2 capture to injection, was accomplished.

Because an existing boiler plant was retrofitted for application of oxyfuel, performance design for determination of ASU and CPU specifications and additional equipment installation with a limited layout were required. Therefore, the status inspection of existing facilities and commissioning for performance demonstration were conducted before the retrofit. The retrofit work was carried out after data necessary for designing was collected. In addition, since behavior unexpected at the time of design frequently occurred while the retrofitted plant was operated, adjustments for stable operation were conducted one after another during the commissioning and the demonstration. Furthermore, since the staff members working in the plant had to operate and maintain not only the boilers but also the facilities such as the ASU and CPU, which do not exist in conventional power plants, considerable efforts were required to learn and master the techniques. In such circumstances, as a result of support from equipment suppliers and efforts made by the staff members of the plant, long-term operation of the oxyfuel plant and CO_2 capture were achieved.

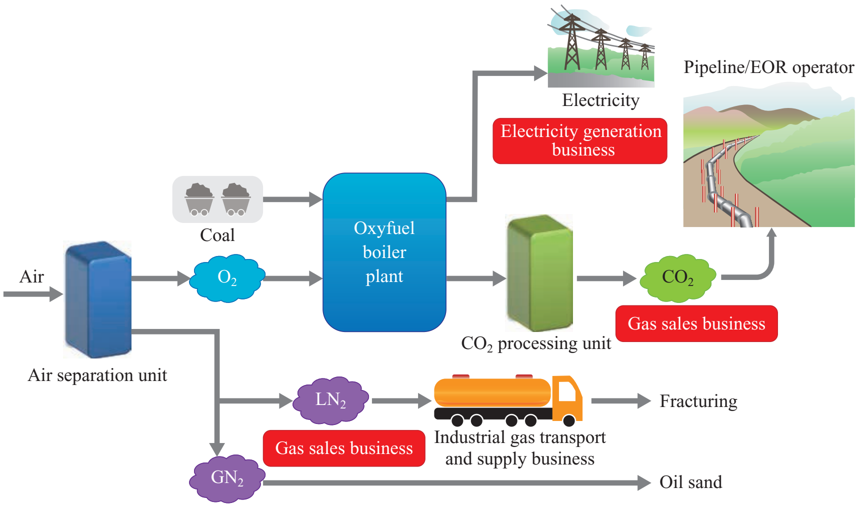
Toward the next project

At present, we are actively developing a project that aims to realize large scale commercial facilities with a CO_2 capture system from an oxyfuel plant.

While this technology is to be applied to power generation plants, the possibility of not only capturing CO_2 but also industrially utilizing CO_2 (CCUS: Carbon Capture, Utilization,



Injection site of captured CO_2



Business scheme design for the large scale oxyfuel project

and Storage) has been considered in recent years. CCUS raises the value of captured CO_2 and realizes economically effective CO_2 capture. For example, captured CO_2 can be utilized for EOR (Enhanced Oil Recovery) which increases oil production from oil fields where oil production has decreased. Furthermore, since oxyfuel technology generates nitrogen separated by an ASU, the utilization of nitrogen can also contribute to improved economic efficiency. Shale gas production (fracturing) and fertilizer production are examples of nitrogen utilization. Improvement in economic efficiency by measures such as the marketing of such by-products opens up possibilities for the capture technology of CO_2 from oxyfuel.

If the oxyfuel technology is applied to the coal-fired power plant, economic efficiency can be improved by utilizing captured CO_2. In addition, selling nitrogen generated by the ASU for industrial use can provide an economically advantageous CCS system.

Conclusion

Oxyfuel boiler systems can not only be constructed as new plants but existing plants can also be retrofitted into CO_2 zero emission plants. We strongly believe that this is an important technology. We will make use of our abundant experience in plant operations obtained from the demonstration in the Callide Oxyfuel Project and create a develop power generation system with CO_2 capture on a commercial scale. Optimization of processes that vary between projects and the development of more effective systems are important issues as well.

We will continue to put forth efforts for early commercial implementation and to achieve more advancements in order to realize the idea of an economically effective and highly efficient CO_2 capture system.

Inquiries:
Business Development & Sales Department,
Boilers Business Unit,
Resources, Energy & Environment Business Area,
IHI Corporation
Phone: +81-3-6204-7414
https://www.ihi.co.jp/en/