

Making Effective Use of Unused Energy — Utilization of the Twin IHI Gasifier —

TIGAR[®] (Twin IHI Gasifier) gasifies lignite, biomass, and so forth for various purposes

TIGAR[®] is based on circulating fluidized bed technology, and it is operable at a lower temperature and pressure compared with other gasifiers. It can gasify unused fuel, such as lignite, and is characterized by a great gasification process with an excellent operability and economic efficiency. IHI has started a project to demonstrate its abilities, taking one step closer towards commercialization!!

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Full view of the demonstration plant (50 t/d) in Indonesia (TIGAR[®] gasifier structure seen in the center)

Recently, news about unconventional energy resources — for example, the realization of mass production of shale gas in the U.S. and oil sand in Canada — have become hot topics. In the first place, among the various energy sources that are used around the world such as fossil fuel (including petroleum, natural gas, coal), nuclear energy, and renewable energy, fossil fuel plays a major role due to its high energy density, ease of transport, and excellent usability. Coal, among others, serves as an important energy source in many countries for the following reasons: it has the largest recoverable reserves; it is evenly distributed around the world; and its unit price per calorific value is lower and its price is more stable compared

to petroleum and natural gas. However, over 50% of the coal reserves is low-rank coal, such as lignite and subbituminous coal, and its calorific value is low because it contains a lot of water and oxygen. In particular, lignite is unsuitable for long-distance transportation or storage because it is prone to combust spontaneously, thus, it is used only for limited purposes (for example, as fuel for power plants in the vicinity of coal mines) and has not been fully utilized.

Hence, technologies for utilizing the aforementioned unused coal are becoming more important, including technologies that gasify solid raw lignite or other low-rank coal so as to enable high-efficiency power generation or to synthesize

ammonia, methanol, methane, or other liquid fuel using carbon monoxide and hydrogen, which constitute syngas, so that they can be used as chemical raw materials. Gasification is the key to these technologies, so research and development for various gasification technologies is being carried out across the world.

Coal gasification technology (twin gasification)

A gasification system refers to a technology that uses the thermal decomposition of solid raw material and the gasification reaction of carbide called coal char to convert the solid raw material into gases including carbon monoxide and hydrogen. The gasification reaction is an endothermic reaction: heat needed for gasification is supplied by partially oxidizing with air or oxygen. Oxygen, steam, air, or the like is used as a gasifying agent. Various types of gasifiers, including fixed bed gasifiers, entrained bed gasifiers, and fluidized bed gasifiers, have been developed, and each gasifier type has inherent characteristics. Since 2004, IHI has been promoting the development of TIGAR[®], leveraging circulating fluidized bed boiler technology with a focus on lignite in light of the fact that with a large proportion of lignite resources remaining unused, there are expectations for technologies that utilize lignite efficiently.

The TIGAR[®] is a combination of a circulating fluidized bed combustor and a bubbling fluidized bed gasifier, which is based on fluidized bed technology, i.e., a technology intended to combust or gasify fuel in high-temperature sand. The term “twin” refers to the two furnaces that constitute the TIGAR[®], which are the gasifier for gasification reaction and the combustor for combustion reaction. After solid raw material such as lignite is poured into the gasifier, it is thermally decomposed and allowed to react with the gasifying

agent. As a result, it is converted into syngas consisting mainly of carbon monoxide and hydrogen. Steam is used as the gasifying agent, which is produced through heat recovery from syngas and exhaust gas. The unreacted portion of the coal char generated in the gasifier is entrained in the circulating bed material and transferred to the combustor, where it burns in the air and supplies heat to the circulating bed material. The circulating bed material and the exhaust gas are then separated using a device called a cyclone. The separated circulating bed material is returned to the gasifier to supply heat needed for the gasification reaction.

Verification with a pilot plant (6 t/d)

Following the elemental study, a pilot plant capable of accommodating a continuous gasification test with a lignite feed amount of around 6 t/d was constructed at the Yokohama Works beginning in fiscal 2006.

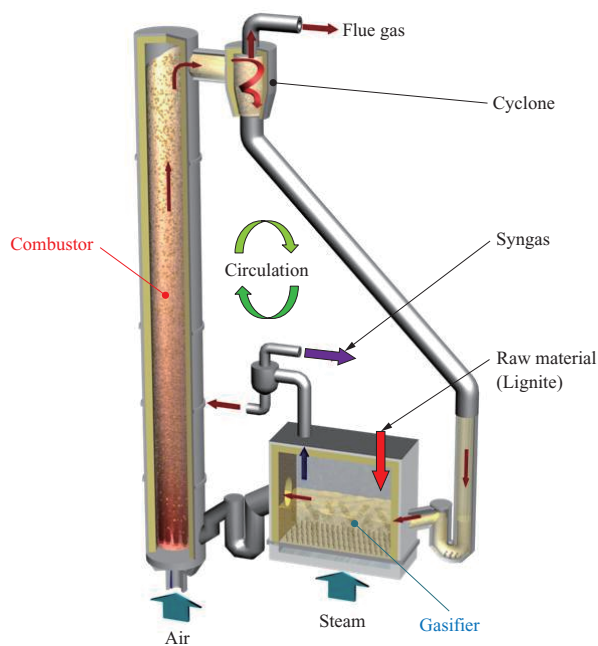
The object of this pilot plant was to obtain design data and verify the feasibility of ensuring plant stability during continuous operation with a view to the next development step, i.e., the Indonesia Demonstration Project using a demonstration plant (50 t/d). The pilot plant is equipped not only with gasification functionality but also with gas purification equipment, which removes tar and ammonia nitrogen in the syngas, as well as waste water treatment equipment, which treats waste water produced in the gas purification process. A set of component equipment necessary for a gasification plant was assessed by conducting a continuous gasification test. Indonesian lignite with a moisture content of around 30 to 45% was used as the gasification feedstock.

Composition of syngas

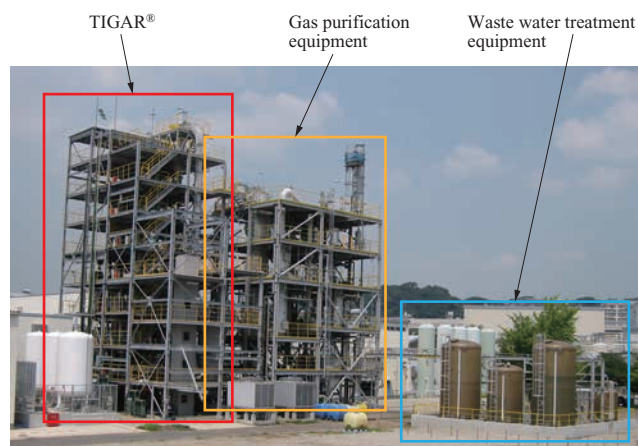
The lignite gasification test with the pilot plant revealed that the syngas was typically composed of hydrogen, carbon monoxide, carbon dioxide, methane, and so on. In addition, the test results demonstrated that a high concentration of hydrogen, which is a feature of steam gasifiers, could be obtained and that the syngas was virtually free from contaminants, such as nitrogen.

Stability of continuous operation

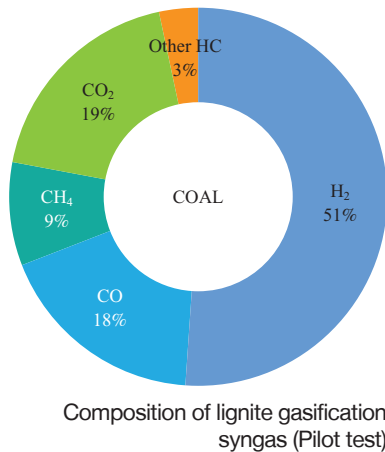
The trends during continuous gasification operation with over



Basic structure of TIGAR[®]



External view of the pilot plant (6 t/d)



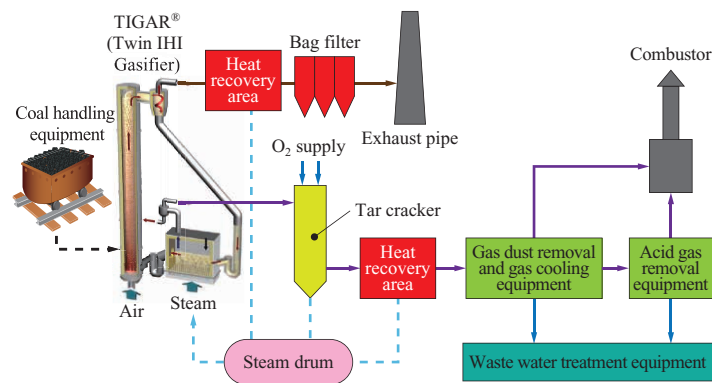
Composition of lignite gasification syngas (Pilot test)

100 hours indicated that both the gasifier temperature and the combustor temperature were almost constant, thus confirming that stable gasification operation is feasible. Moreover, no sharp fluctuations in the temperature of the components or gasification status were observed despite changing the coal fed into the plant while in operation from lignite containing 42.8% moisture to lignite containing 34.3% moisture, thus confirming that it is a highly robust equipment.

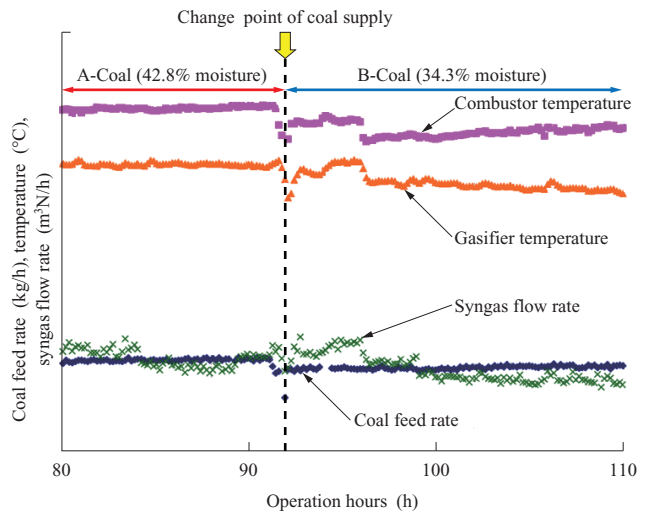
Beginning in fiscal 2010, we started identifying issues for the demonstration plant and conducting verifications of elemental technologies with the aid of the Ministry of Economy, Trade and Industry. Subsequently, the next step — the Indonesia Demonstration Project — was started in fiscal 2012 with the successful completion of the continuous operation test of the pilot plant.

Indonesia demonstration project

We had constructed a TIGAR[®] plant which can feed 50 t/d of Indonesian lignite at the Kujang Factory of the under the control of PT. Pupuk Indonesia Holding Company (PIHC). And we have a plan to conduct a variety of gasification demonstration operation until the end of fiscal 2016. The Kujang Factory is located about 75 km southeast from Jakarta, and goods can be transported by land delivery from the factory of PT. Cilegon Fabricators (IHI's overseas affiliate) to this location in approximately two hours.



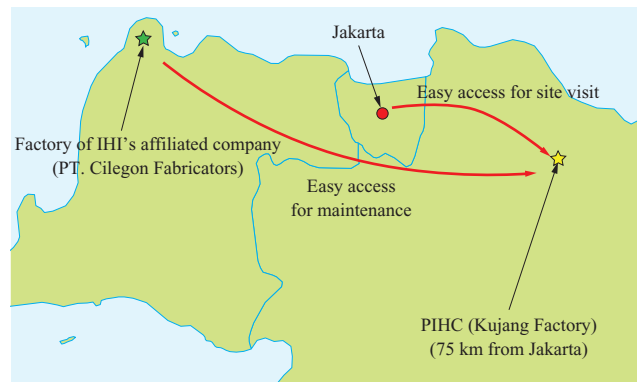
Demonstration plant process flow



Pilot plant operation trends

Demonstration project overview

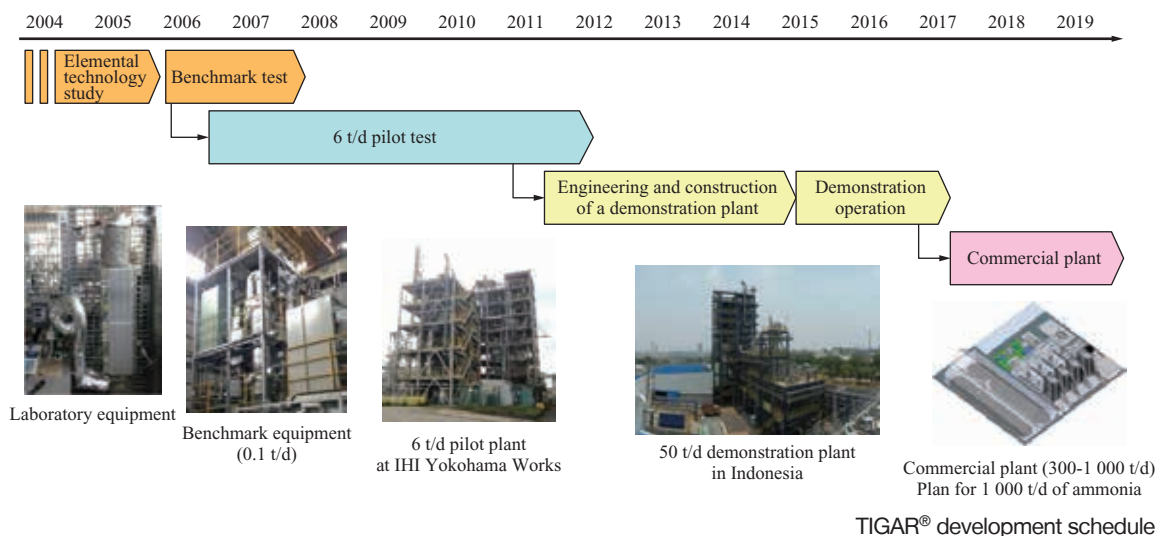
Based on the assumption that the syngas is used at an ammonia fertilizer factory, verification is conducted on the hydrogen production process of the demonstration plant. In order to produce hydrogen needed for ammonia synthesis as a final product, the following are required: TIGAR[®]; tar cracker intended to remove tar from the syngas; exhaust heat recovery; gas cooling and gas dust removal; gas shift process in which carbon monoxide in the syngas is converted into hydrogen;



Indonesia demonstration project site



Coal unloading at the port near the demonstration project site



and a process in which acid gas (CO_2 , H_2S) is removed from the syngas.

Coal used to demonstrate the operation is lignite (coal brand, “PKN Coal”: 3 400 kcal/kg GAR at 43% moisture) procured from East Kalimantan by PT. IHI Gasification Indonesia (IHI’s local subsidiary) and then transported to and used at the project site. We have a plan to conduct a study using lignite with a higher moisture content and biomass going in the next step.

Progress of the demonstration project

Following the execution of a contract with an Indonesian fertilizer factory in February 2013, the construction of the demonstration plant was started in October of the same year. The construction was completed about one year later, and the plant was brought into commissioning operation, which concurrently served as coal gasification operation, in December 2014. At the beginning of fiscal 2015, the commissioning operation started to the demonstration operation stage. We expect the demonstration operation to provide an opportunity for operators dispatched from the fertilizer factory to acquire operating skills so that they will be able to provide guidance on the operation of the commercial plant in the future.

In the following period of about two years up until the end of fiscal 2016, the demonstration project will implement thousands of hours of demonstration operation, thereby validating the scale-up design, verifying the maintainability and durability of the plant when it is operated for a long period of time, and performing a demonstration jointly with the fertilizer factory.

Efforts toward commercialization

In Indonesia, a national policy for increasing the coal utilization rate (currently at 24%) to 31% by 2025 is being pursued.

On the other hand, the production of natural gas is decreasing year by year, and it is predicted that its price will greatly increase in the next few years. As such, fertilizer companies that use a lot of natural gas would like to quickly shift its raw material from natural gas to coal syngas. This means that if product gas from lignite gasification can replace expensive



Control room for TIGAR® demonstration plant
(Training on operation for Indonesian operators)

natural gas, fertilizer companies will be able to reduce running cost because lignite is cheap and abundant in Indonesia. In addition, given that such replacement is possible, the country can export its surplus of natural gas, thereby securing a precious source of foreign currency income. An increase in Indonesia’s natural gas export capacity is favorable to Japan as well in terms of energy security. The ongoing demonstration project is intended to verify Indonesia’s first long-term operation and gasification with Indonesian lignite. We will pursue the early realization of a commercial plant by reflecting the verification results in commercial design, as well as by working to improve the reliability and demonstrating the excellent applicability of the TIGAR®.

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