

High-pressure Pump – CO₂ Injection Pump –

The CO₂ injection pump plays an active role as a part of the Enhanced Oil Recovery (EOR) process that injects carbon dioxide (CO₂) into the oil layer and recovers crude oil efficiently. When this process is performed, carbon dioxide, which is collected from emitted gas at energy production or other industries, is utilized in some cases. There is high expectation for this oil recovery process because it can also serve as a carbon capture and storage (CCS) process for preventing the release of large quantities of carbon dioxide into the atmosphere. This article introduces the roles and characteristics of the CO₂ injection pump as an application example of a high-pressure pump.

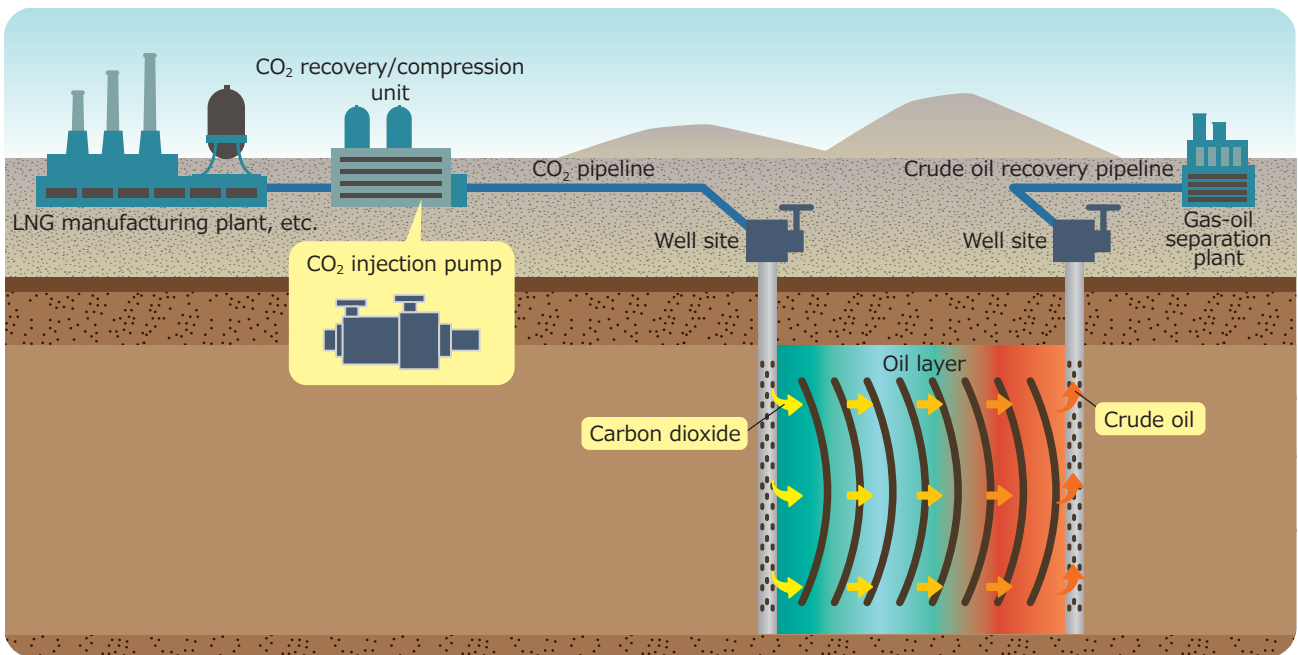


Fig. 1 Schematic showing CO₂-EOR process

Roles of CO₂ injection pump for EOR process

There is a method of recovering crude oil from underground deposits called the “primary recovery method.” This method recovers crude oil by means of a natural blowout (or uncontrolled release of crude oil) from underground deposits. The recovery factor during the primary recovery stage, however, is only about 10% of the deposits. After this primary recovery stage, the secondary recovery method¹⁾ is applied. The secondary recovery method recovers crude oil by injecting water (water injection scheme) or associated gas into the ground. Furthermore, tertiary recovery methods, which make it easier to recover the crude oil by reducing its viscosity, are also applied. Three

techniques are used for the tertiary recovery methods: thermal recovery (steam injection), gas injection (carbon dioxide, nitrogen, etc.), and chemical injection (polymer, etc.). The general term for these tertiary recovery methods is Enhanced Oil Recovery (EOR) process.

One of the EOR methods drawing attention at present is carbon dioxide gas EOR (CO₂-EOR). CO₂-EOR utilizes the characteristics of carbon dioxide and crude oil.

When carbon dioxide is injected into the oil layer, it is dissolved in crude oil, improving the liquidity of the crude and making it easier to extract.

The CO₂ injection pump is used in the mechanism for increasing the pressure of carbon dioxide and feeding it to an injection well in order to inject carbon dioxide into the oil layer.

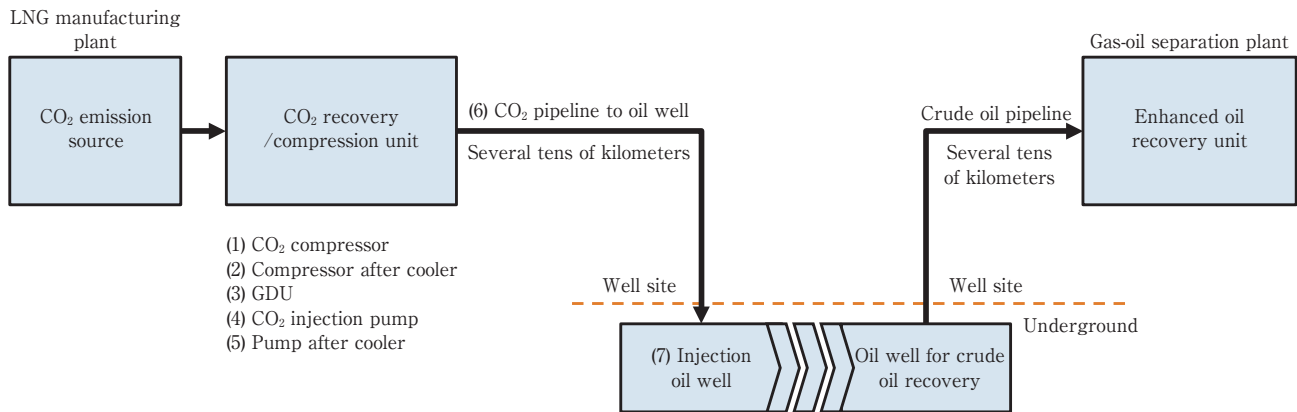


Fig. 2 CO₂-EOR process flow

After various gases emitted at facilities (such as power stations, natural-gas purification plants, and fertilizer manufacturing plants) are separated and recovered, carbon dioxide gas is utilized for the injection process. A part of this carbon dioxide, injected in a voided space from which crude oil was extracted, remains and is stored in the oil layer. For that reason, this process is considered to be a type of carbon dioxide CCS process.

This article outlines the CO₂-EOR process by focusing on the mechanism for increasing the pressure of carbon dioxide and describes the characteristics of CO₂ injection pumps based on the double-casing, multi-stage centrifugal pumps Ebara has supplied to plants in North America and the Middle East.

Outline of CO₂-EOR process

First, carbon dioxide recovered from a liquefied natural gas (LNG) manufacturing plant is compressed and its pressure is increased in order to produce supercritical CO₂. Next, supercritical CO₂ is injected into the injection oil well via a CO₂ pipeline. Lastly, the crude oil extracted from the crude oil recovery oil well is transported through a pipeline to a gas/oil processing plant that processes crude oil. In this manner, the crude oil is recovered (**Figures 1 and 2**).

The equipment (1) to (7) shown in Fig. 2 constitutes the main components used for injecting carbon dioxide into an oil well from a LNG manufacturing plant. The CO₂ injection pump is one of the main components of this process. The functions of the equipment used are described below.

(1) CO₂ compressor

This machine is a multi-axial, multi-stage compressor, which is installed upstream of this plant. The carbon dioxide recovered from a LNG manufacturing plant is compressed from gas phase to supercritical phase that causes its pressure to increase.

(2) Compressor aftercooler

After carbon dioxide is subjected to adiabatic compression by the CO₂ compressor, this will cause its temperature to increase. This machine is used to cool down the carbon dioxide to a temperature at which its pressure can be increased using Ebara's CO₂ injection pump.

(3) Glycol dehydration unit

This machine is called "GDU" (glycol dehydration unit or gas dehydration unit). GDU removes the water content dissolved in carbon dioxide by absorbing the water content in triethylene glycol. The CO₂ compressor redirects the flow of carbon dioxide to GDU before it reaches its supercritical phase from the compressor intermediate stage. GDU removes the dissolved water content to almost 0.01% in terms of mole fraction, and then returns the carbon dioxide to the subsequent stage of the CO₂ compressor. In this way, any blockage in a pipeline caused by solidifying of the dissolved water content in the event of unexpected adiabatic expansion and other troubles can be prevented.

(4) CO₂ injection pump

After CO₂ compressor increases the pressure of carbon dioxide to its supercritical phase, the CO₂ injection pump increases the pressure of carbon dioxide even further so that a high pressure state is produced in

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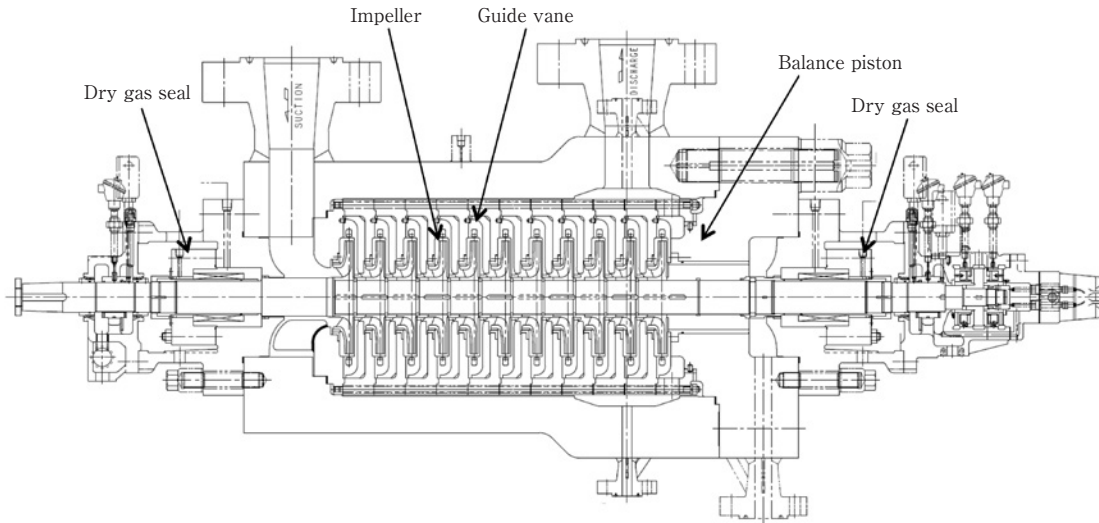


Fig. 3 Cross section of CO₂ injection pump

order to deal with the pipe resistance of a long pipeline and underground pressure. The CO₂ injection pump produces a high pressure of about 13 MPa in terms of the pressure difference before and after the pump.

(5) Pump aftercooler

After carbon dioxide is subjected to further adiabatic compression by the CO₂ injection pump and its temperature has increased, this machine cools down the carbon dioxide to a temperature optimal for pipeline transportation.

(6) Pipeline

A pipeline connects a carbon dioxide recovery plant to the crude oil well site. Some of the pipelines are approximately 300 kilometers long.

(7) Oil well

There are two oil wells in this configuration. One well is used for injecting carbon dioxide transported through a pipeline. The other well is used for extracting the crude oil, which flows out from the well because the carbon dioxide injection lowers the viscosity and causes an increase in the flow rate.

Characteristics of CO₂ injection pump

Since supercritical carbon dioxide (see “Commentary” given below) is a compressible fluid, a lot of considerations have been incorporated into this pump design, which is different from the design of a pump that handles incompressible fluid (such as water) in normal temperature.



Fig. 4 External appearance of CO₂ injection pump

Commentary

Supercritical carbon dioxide

When carbon dioxide exceeds its supercritical point (pressure: 7.4 MPa, temperature: 31 °C/87.8 °F), it will be put in a supercritical fluid state that has interim properties between liquid and gas. Supercritical carbon dioxide is a compressible fluid, and has a liquid-like heavy density and a light viscosity that is almost gas like. Furthermore, supercritical carbon dioxide has both the diffusivity of gases and solubility of liquids and is used for crude oil recovery because the carbon dioxide dissolved in crude oil causes its liquidity to increase.

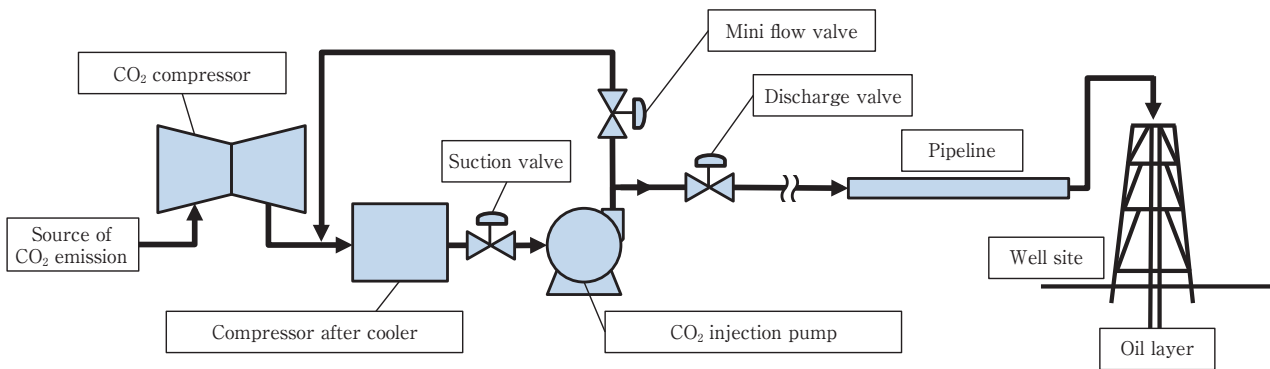


Fig. 5 Configurations of peripheral equipment of CO₂ injection pump

The Model DCS high-pressure pump (**Figure 3**) is an Ebara CO₂ injection pump that meets the extremely stringent API610-compliant specification requirements. This pump has a double-casing structure with a carbon steel outer casing that enables highly reliable operation even under a high-pressure environment. A total 11 stages of impellers are arranged in the same direction. The axial thrust load in the coupling direction produced by each impeller is canceled by a balance piston.

The impeller diameter of the CO₂ injection pump has been set based on a calculation that has provides consideration for the thermodynamic properties of supercritical carbon dioxide. The performance is calculated by assuming the pump shaft power as an increase of fluid enthalpy.

Furthermore, the CO₂ injection pump is capable of safe and stable continuous operation even for injecting special fluids such as supercritical carbon dioxide. Therefore, the shaft seal of this pump is an extremely important element. A dry gas seal, which causes no contact between the sliding surfaces during operation, has been used as the shaft seal of the latest pump.

Figure 4 shows a photo of the external appearance of the CO₂ injection pump.

Operation of the CO₂ injection pump

CO₂ injection pump handles supercritical carbon dioxide. Therefore, the operation of the pump has distinct characteristics. **Figure 5** shows the configuration of the peripheral equipment of the CO₂ injection pump.

(1) Preparation before starting the pump

Before the pump is started, the pipeline is filled with carbon dioxide by operating the CO₂ compressor alone. If the pipeline is filled with supercritical carbon dioxide in a condition where pressure is increased by the pump when the pipes are empty, dry ice is produced by sudden adiabatic expansion and causes the pipeline to be blocked. The time required for this filling process by compressor varies depending on the entire length of a pipeline. For example, it requires two to three days to fill up an approximately 80km pipeline.

(2) Starting the pump

When the pressure in the pipeline exceeds a certain level, filling and venting (air release) to and from inside the pump is performed gradually. Next, the pump is started with a full open suction valve, full close discharge valve, and open mini flow valve in the same way as starting a standard high-pressure pump. Once the pump is started, the mini flow valve and discharge valve are switched gradually. If the valves are switched suddenly, dry ice is produced and will cause pipeline blockage.

(3) Steady-state operation

After the mini flow valve and discharge valve are switched, the steady-state operation will finally start. After the steady-state operation starts, the pump should be operated by monitoring the operation data (such as flowrate, head, power consumption, bearing temperature, and shaft vibration) in the same manner as a standard high-pressure pump in order to confirm that the pump is in a stable condition.

Pump engineer's comment

When I conducted an installation site test run of a CO₂ injection pump equipped with a dry gas seal for the first time, I encountered several trouble symptoms. We made repeated adjustments and test runs of the auxiliary equipment over and over again together with in-house and outside engineers. I still remember clearly the joy I felt when at last all problems were resolved. Incidentally, there was a thought-provoking event that occurs only when a special fluid such as supercritical carbon dioxide is handled by a high-pressure pump. This event caused some parts to become very hot and other parts to freeze. Because I faced this event for the first time, it left a strong impression on me. It made me realize that the CO₂ injection pump with a dry gas seal is a highly unique pump and requires special start-up and operation procedures.

The adoption of CCS and EOR techniques is expected increase more than ever due to global warming and depletion in oil resources. To meet such expectations, Ebara as a manufacturer of pumps that play an important role in increasing the pressure of carbon dioxide and its transportation, intends to accumulate knowhow and contribute to world needs. We will continue our efforts for designing and manufacturing multi-stage high-pressure pumps capable of handling high-purity supercritical carbon dioxide and conduct tests at the installation sites to ensure reliability.

Reference

- 1) Fiscal 2015 Report on promotional projects such as technology diffusion of measures for global warming mitigation (Studies of the possibilities of using the CCS process for onshore oil field in Mexico), MITSUI & CO., LTD., Mitsubishi Research Institute, Inc.

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