Featured Articles

Hitachi's Water Business Activities in the Oil & Gas Industry

Hisashi Isogami, Ph.D.
Kiyokazu Takemura
Tang Chay Wee
Katsumi Shida
Takahide Nagahara, Dr. Eng.

OVERVIEW: Based on a background of growing demand for oil throughout the world, the International Energy Agency has predicted global oil demand in 2015 of 93.6 million barrels per day, an increase of 1.1 million barrels per day. Accompanying this, new requirements are emerging for water treatment, with the injection of water into oil-bearing layers to increase the volume extracted becoming part of conventional oil production practice, and with unconventional oil production from sources such as oil sands or shale oil requiring water-using extraction techniques not used in the past. Given this background, Hitachi is contributing to making the most of limited water resources at oil and gas production sites by supplying solutions to these needs that utilize the extensive water treatment technologies it has cultivated up to now.

OVERVIEW OF WATER TREATMENT IN THE OIL & GAS INDUSTRY

THERE is growing demand in the oil and gas industry for water treatment systems that comply with environmental regulations, which are becoming increasingly strict every year, with the treatment of water produced as a byproduct of oil and gas extraction being a particular problem. Furthermore, this increasing requirement for water treatment systems is being driven by economic as well as environmental factors, with large amounts of water being used in recent years as a means for the efficient extraction of limited resources.

In the case of conventional oil production sites, for example, because the pressure in the oil-bearing layers falls the longer a well remains in production, it is common to use "waterflooding" to promote oil extraction by injecting water to maintain this pressure. Waterflooding requires the use of sulfate removal units (SRUs) to eliminate sulfate prior to injection because of the role it plays in scale formation. The injection pumps that pressurize the treated water to high levels are another vital piece of equipment.

Unconventional oil production sites, too, require a variety of water treatment equipment to provide water for extracting the oil from oil sands (which are mined using opencast practices) and steam for the recovery of bitumen by steam assisted gravity drainage (SAGD), or the water used for extracting shale oil or shale gas by fracking.

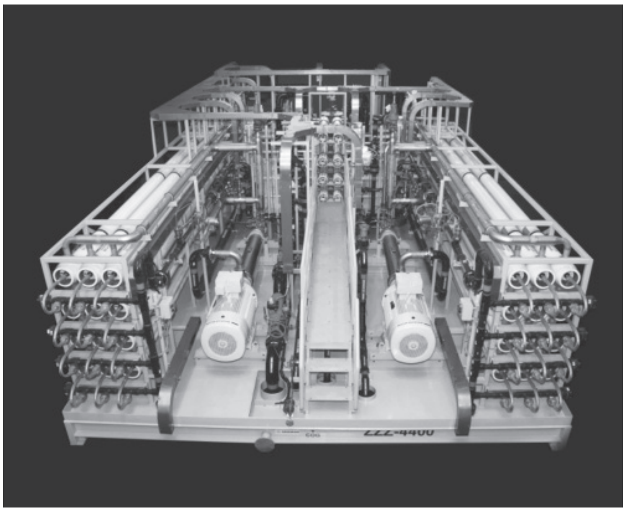
As the water treatment equipment used in the oil and gas industry operates under unusual conditions, it is subject to numerous constraints, such as limits on space and the need for resistance to corrosion, oil, and heat. Accordingly, the industry requires equipment that can satisfy these demands. The water treatment equipment used on offshore oil platforms or floating production, storage and offloading systems (FPSOs), for example, requires special specifications in order to satisfy performance requirements within the very limited space available.

Hitachi has entered this market and is expanding its presence by drawing on its extensive knowledge of water treatment technology to supply solutions that meet the particular needs of various different sites operated by the oil and gas industry. This article describes some of the recent activities of Hitachi, including SRUs, a seawater desalination system for FPSOs (see Fig. 1), and injection pumps.

OVERVIEW OF SRUS AND HITACHI'S ACTIVITIES

Need for Sulfate Removal

When seawater is injected into oil wells to improve oil recovery, the ions in the seawater can react with water and clay inside the well to form deposits (scale) that reduce the ability to recover oil by blocking the pores in the well. In particular, there is a need to deal with the sulfate (SO_4^{2-}) present in seawater in a concentration of several thousand milligrams per



RO: reverse osmosis
FPSO: floating production, storage and offloading system

Fig. 1—RO Unit for FPSOs.
This RO unit for FPSOs has the capacity to treat 1,200 to 2,226 m^3 of water per day. Hitachi has already supplied six of the units, with three more currently in production.

liter. This sulfate reacts with barium ions (Ba^{2+}) and strontium ions (Sr^{2+}) in the well to form deposits of barium and strontium sulfate ($BaSO_4$ and $SrSO_4$).

Furthermore, any sulfate that gets into the well is readily transformed into toxic and corrosive hydrogen sulfide (H_2S) by the action of sulfate-reducing bacteria, creating an acidic environment in the well and resulting in corrosion of various down-well equipment. Accordingly, the control of sulfate is particularly necessary if seawater is to be used for injection.

Sulfate Removal Method

Past practice for preventing the formation of scale due to sulfate was to deposit large quantities of scale inhibitor into the well. However, the lack of uniformity in well characteristics makes selecting the best chemical to use and controlling its concentration difficult, so much so that getting the conditions wrong can actually promote scale formation inside the well.

Nano filtration (NF) membranes, a recent development, have attracted attention as a potential technique for removing sulfate from injection water. A feature of NF membranes is that, whereas ions with a single charge can pass through largely unimpeded, the membranes can efficiently separate ions with a double charge. This makes them ideal for the removal of sulfate ions, which have a charge of –2, and when used on seawater with a sulfate concentration of several thousand milligrams per liter, they can reduce the concentration to below 100 mg/L. Because NF membranes are used at much lower pressures and can recover 1.5 to 2 times as much water as the reverse osmosis (RO) membranes used for seawater desalination, they also have potential economic advantages. Furthermore, because NF membranes also filter out microorganisms such as sulfate-reducing bacteria, they can significantly reduce the risk of oil wells being fouled or becoming acidic.

With the technology now starting to be used not only in offshore oilfields such as the North Sea or off the coast of Brazil, but also in onshore fields such as those in the Middle East, the scope of its use is expected to expand rapidly in the future.

Sulfate Removal System Implementation

Because the condition of seawater varies widely depending on the location and time of year, the choice of pre-treatment system is important for preventing severe fouling of NF membranes and maintaining stable membrane filtration performance. Pre-treatment systems are typically chosen based on the condition of the seawater (presence of organic matter, turbidity, any plankton or other microorganisms) from a range of options that include simple filters, sand filters (such as multimedia filters), and micro-filtration (MF) or ultra-filtration (UF) membrane filters. In particular, membrane filtration has been selected in many recent projects, especially offshore facilities, not just because it is easy to maintain and delivers good water quality, but also for its other advantages that include installation space and equipment weight.

Hitachi is able to draw on its many years of experience with water treatment to supply the right sulfate removal system for each project. By combining these with its information and communication technology (ICT), Hitachi aims to implement systems that satisfy the varying requirements of customers, including for operation and maintenance.

OVERVIEW OF SEAWATER DESALINATION SYSTEMS FOR FPSOS AND HITACHI'S ACTIVITIES

Hitachi Aqua-Tech Engineering Pte. Ltd. (HAQT) markets seawater desalination systems that feature excellent energy efficiency for a variety of applications. Recent years have seen growing demand for these systems in applications such as offshore oilfields in particular, which are characterized by restrictions such as space and power supply. HAQT has overcome these obstacles by developing technology for more compact and energy-efficient systems, and by equipping them with enhanced corrosion and vibration resistance to enable them to operate on offshore rigs or platforms.

FPSOs have been used by the oil and gas industry for the last 30 years, with many of them currently operating in offshore oilfields. FPSOs are moored on the ocean like a boat, where they receive the crude oil, water and other material produced by an offshore oilfield. The mooring method used depends on the conditions, with multi-point moorings being used in calm waters, and independent moorings being used in waters prone to cyclones or hurricanes. These independent moorings allow the FPSO to be disconnected from the mooring during storms and then reconnected after the bad weather has passed.

FPSOs have the following advantages.

- Can be relocated and reused
- Minimize need for offshore construction, faster startup of production
- Able to be used in a wide range of maritime climates

Moreover, with the advances in moorings and undersea equipment over the last few years, FPSOs can now be used in deeper waters and stronger currents than before.

HAQT supplies seawater reverse osmosis (SWRO) equipment for seawater desalination on FPSOs. This SWRO equipment is commonly used on FPSOs as oil dilution and water treatment systems. The equipment is customized to suit the following conditions.

- Drinking water
- Water for general use
- Cooling water
- Water containing dilute oil

The rinse water used to dilute crude oil in order to remove the salt and water requires a high level of water quality. This rinse water dissolves the salt contained in the crude oil. Because any solids or salt contained in the rinse water will contaminate the crude oil and will need to be removed by subsequent processing, it is necessary to eliminate these impurities beforehand. SWRO systems are primarily used for this purpose as they can produce rinse water on the vessel with consistent quality.

Underpinned by demand from the FPSO market, HAQT supplies products that are customized to suit a wide range of requirements.

INJECTION PUMPS

Product Overview

Injection pumps operate at high pressure and are used for waterflooding, a technique classified as a secondary recovery method for the production of crude oil. In contrast to primary recovery, whereby the oil is forced to the surface by the natural pressure of the underground oil-bearing layers, secondary recovery methods are those that increase production volume by forcibly increasing the flow of oil through the oil-

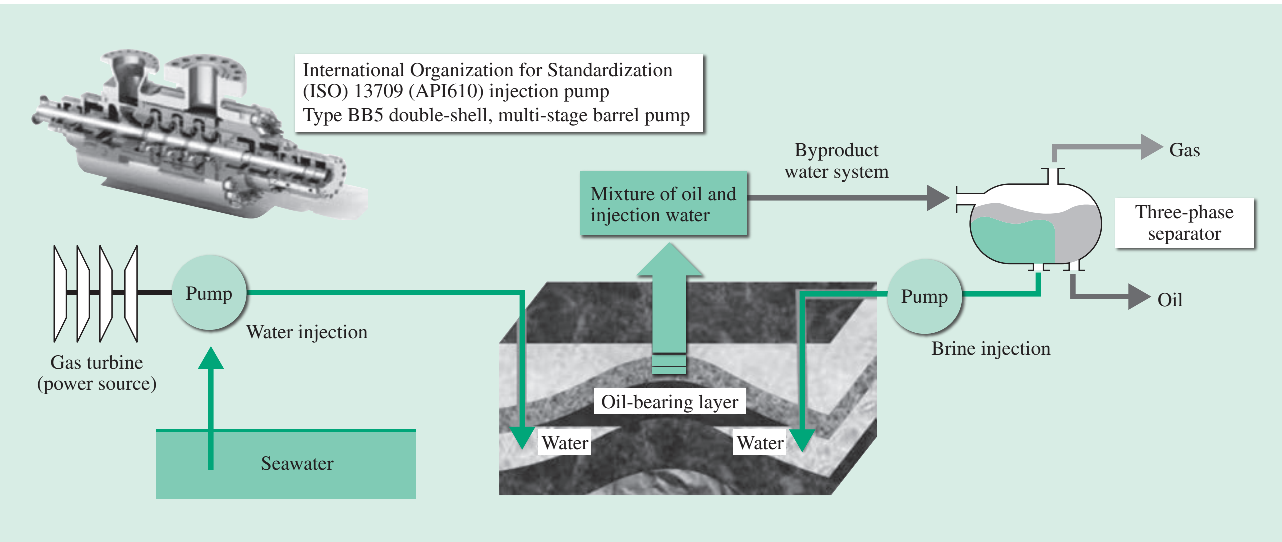


Fig. 2—Overview of Crude Oil Extraction System Using Secondary Recovery Method.
A water injection pump is one that injects a fluid, such as water drawn from the ocean, into the oil-bearing layer. A brine injection pump, on the other hand, is one that re-injects water that has been separated from the fluid mixture extracted from the oil-bearing layer in a three-phase separator. Both types of pump increase production of crude oil by improving the flow of fluid through the oil-bearing layer.

bearing layers. Waterflooding is one such method and it works by using a pump to inject pressurized water. As primary recovery is typically believed to extract only around 30% of the available oil, the current growth in the international consumption of oil means that the use of other methods such as waterflooding to increase the production of existing oil fields has become an essential addition to the discovery of new fields. Fig. 2 shows an overview of an oil extraction system that uses a secondary recovery method.

In response to this situation, Hitachi has developed and commercialized new injection pumps that feature high reliability and high performance for use in waterflooding. The main features are as follows.

(1) Compliant with International Organization for Standardization (ISO) 13709 (API610) standard

(2) Help reduce life cycle costs (including maintenance) by providing high efficiency and pumping performance thanks to the use of highly accurate computational fluid dynamics (CFD) to redesign the shapes of the impellor and other fluid power components.

(3) High reliability achieved through the use of dual-phase stainless steel that provides both high strength and resistance to corrosion when used to pump seawater.

(4) High level of operational reliability thanks to low-vibration operation achieved through the evaluation and testing of rotor dynamics.

(5) A range of shaft seals and bearings available to suit different conditions, with auxiliary components that feature compact design and long operating life.

Development Technology for High-performance Fluid Power Components

The BB5 multi-stage barrel pump designed for use as an injection pump contains a large number of fluid power components, including the impellor and diffuser. To achieve high performance, it is important to produce optimal designs for the shapes of these components by determining how they interact with the flow. In addition to using highly accurate CFD to simulate the flow through each of these components (see Fig. 3), a high-performance shape design was achieved efficiently by conducting a systematic study of the sensitivity of performance to the shape of fluid power components using a parameter design based on experimental design methods.

CFD: computational fluid dynamics

Fig. 3—Use of CFD to Simulate Flow inside Pump.
The figure shows the pattern of flow through the pump, from the inlet channel to the impellor, diffuser, and return. High efficiency is achieved by making full use of highly accurate CFD.

Summary

These injection pumps have demonstrated both high performance and high reliability, with a discharge pressure of approximately 200 bar (20 MPa), a rated output of 28,000 kW (ISO rating of gas turbine used to drive pump), and a total of more than 13,000 hours of field operation.

Injection pumps are required to operate under a wide range of conditions in terms of both the fluids they are called on to pump and the conditions in the oil-bearing layer. By supplying the oil and gas market with injection pumps that can satisfy diverse requirements with high efficiency and reliability, Hitachi intends to continue contributing to the steady supply of energy.

CONCLUSIONS

This article has described Hitachi's recent activities relating to water supply in the oil and gas industry. Hitachi has already built up a track record of supplying solutions that satisfy customer needs in a variety of fields. By further boosting its involvement, Hitachi intends to continue contributing to achieving both environmental protection and economic development on a global scale.

ABOUT THE AUTHORS

Hisashi Isogami, Ph.D.

Oil & Gas Water Treatment Department, Water & Environment Solutions Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the water treatment business for the oil & gas industry. Dr. Isogami is a member of The Japan Society of Mechanical Engineers (JSME) and the Cryogenics and Superconductivity Society of Japan.

Kiyokazu Takemura

Oil & Gas Water Treatment Department, Water & Environment Solutions Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the water treatment business for the oil & gas industry.

Tang Chay Wee

Managing Director, Hitachi Aqua-Tech Engineering Pte. Ltd. He is currently engaged in the water treatment business for the seawater desalination market.

Katsumi Shida

Desalination & Water Treatment Department, Water & Environment Solutions Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the water treatment business for the seawater desalination market.

Takahide Nagahara, Dr. Eng.

Machinery Systems Division, Industrial Products Company, Hitachi, Ltd. He is currently engaged in developing the fluid dynamics performance of large pumps. Dr. Nagahara is a member of the JSME and the Turbomachinery Society of Japan.