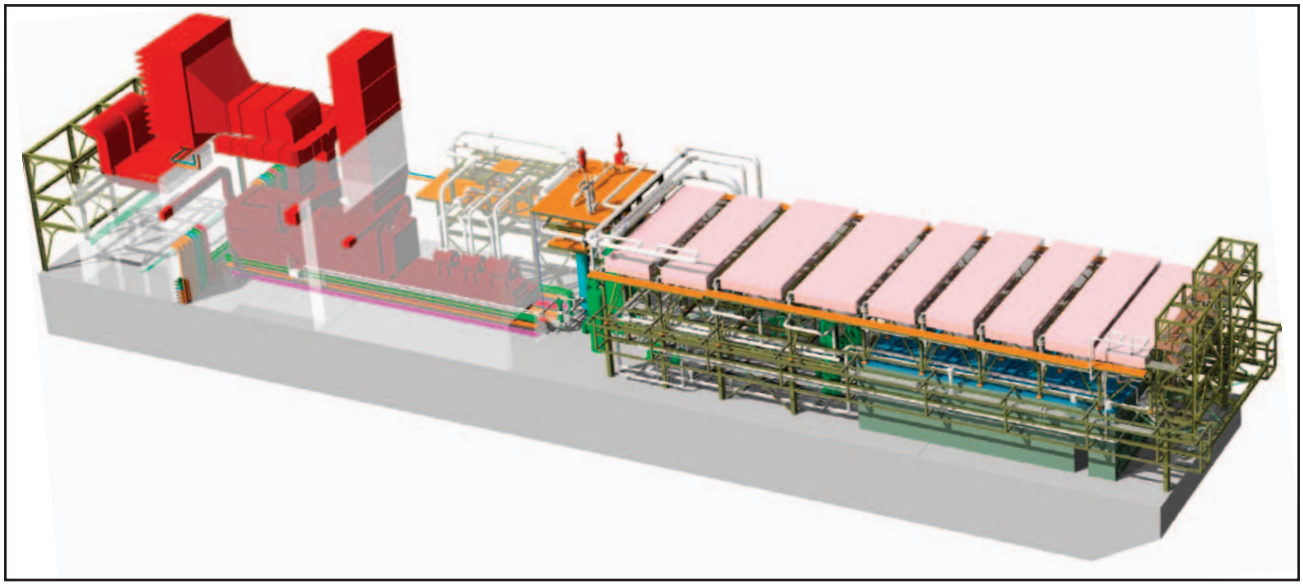

■ **Computer drawing of one of the barges with a complete reinjection system. The structures that have to be dismantled for navigating the Volga River and the successive canals to the Caspian Sea are shown in red. These components will be reassembled in a Caspian yard before reaching the operating site.**

KASHAGAN SOUR GAS REINJECTION PROJECT

Natural Gas with 18% H_2S Is Reinjected Underground at 11,022 psi (760 bar)

By Roberto Chellini

Sour gas, often found in oil fields, imposes several environmental and security problems in order to profitably exploit the oil reservoirs. These problems are proportional to the type of contaminants and their concentration.

The Caspian Sea is presently one of the areas of preeminent interest to international oil companies for its oil and gas resources, in spite of the high concentration of contaminants found in the oil fields of that area. In order to exploit in full the oil reservoirs located in the northeast area of the Caspian Sea belonging to the Kazakh Republic, it is necessary to safely handle the associated gas containing high percentages of H_2S, which can not be dispersed in the atmosphere. This gas is tolerated in only 10 ppm for continuative exposure and considered lethal at 20 ppm. The only way of recovering crude is to process the natural gas used as fuel and other land purposes and reinject the sour gas in the reservoirs at high pressure to sustain oil recovery.

The only compressor manufacturer which has gained experience in reinjection of sour gas at the pressures required by Caspian Sea fields is GE Energy Oil & Gas. The first order dates back to 1999 when the contract for the Karachaganack field was signed (7977 psi [550 bar] reinjection pressure of sour gas with 17% H_2S). This field is now in production.

In 2001, a contract was signed for the Tengiz field reinjection system at 9137 psi (630 bar) with 12% of H_2S.

In mid-2004 the Kashagan contract was signed with AGIP KCO at the conclusion of a conceptual and basic design study jointly carried out by the two partners.

This is the most advanced project in the field both for the reinjection pressure involved, 11,022 psi (760 bar), and the amount of H_2S contained in the gas reaches, 18%.

Due to the harsh environmental conditions found at the Caspian Sea the project is in many ways similar to the Hammerfest LNG project. Also, the two Kashagan modules will be barge mounted and shipped to site fully assembled to minimize site operations. GE Energy Oil & Gas will manufacture the compressors and the gas turbine drivers at the Nuovo Pignone Florence plant, test the complete compressor trains at its Massa testing facilities and then assemble the whole compression systems on the barges built in La Spezia.

GE Oil & Gas has the responsibility for the turnkey supply of the whole compression modules, including the barges.

The barges, 311 ft. (95 m) long and only 52 ft. (16 m) wide, will navigate the Volga and the canals to the Caspian Sea, which are closed due to ice for the entire winter season, beginning in October. Canals and bridges also impose a maximum barge height of 36 ft. (11 m) during navigation. After assembling of the whole plant in La Spezia, all topside structures above 36 ft. (the complete system is 82+ ft. [25+ m] high from barge deck) have to be dismantled and reassembled in a Caspian yard. The machinery will then be protected for one year's storage near the site of final destination.

The Kashagan field is located 37.2 miles (60 km) from the shore in only 9.8 ft. (3 m) deep waters. The barges,

One of the Karachaganack sour gas compressor trains during full load test at the Nuovo Pignone Florence shop in 2001. These compressors, similar to the Kashagan ones, have been in service since 2003, with exceptionally high availability and reliability factors.

six in a row — two from GE Energy Oil & Gas with the Raw Gas Injection (RGI) systems, two for flash gas and two for the process units — will be lifted and welded to four poles at approximately 49 ft. (15 m) height from the waters in order to avoid crashes and deformations by ice floes carried by sea currents and heavy storms.

The poles will have a 164 ft. (50 m) span which unavoidably will provoke a deflection of the barges, which have a weight of over 3000 tons (2721 tonnes). The layout of the compression plant on the barge has been designed taking into account weight distribution to allow a correct navigation and also minimize barge deflection in its elevated position which, according to preliminary calculations, should be 1.77 in (45 mm) in spite of the barges' 18 ft. (5.5 m) hull heights.

The compression train itself — composed of the 30 MW gas turbine driver GE Frame 5D, the step-up gear and three barrel compressors — is assembled on a three-point baseplate which maintains machine alignment independently from barge deflection. However, the balance of the plant, which includes interstage scrubbers and air coolers with thick wall interconnecting piping will have to cope with such a design feature. For enhanced safety, the entire plant utilizes a High Integrity Pressure Protection System (HIPPS). The plant has been sectioned in such a way that avoids pressure build-up in case of failure. The use of safety valves has thus been greatly reduced and the number of flanged connection minimized and positioned, taking into account barge deflection.

This reinjection plant has been designed for the site's ambient conditions, taking into account the very wide temperature range of -32° to 95°F (-36° to 35°C). Low temperature carbon steel F22 has been used extensively, from compressor casings to process piping which, according to pressures, can reach a wall thickness of 2.5 in. (65 mm).

The compressor train features three barrel-type compressor casings in a row. The first is a BCL 304B followed by a BCL 304C and finally a BCL 304E. The 190,699 cu.ft/h (5.4 MSm^3/h) of sour gas handled at the first compressor inlet at 1305 psi (90 bar) is compressed to the final operating pressure of 11,022 psi (760 bar) — the compressor train has a design pressure of 11,603 psi (800 bar).

The compressors are driven by an MS5002D gas turbine rated (43,690 hp (32,580 kW) (ISO) at 4670 rpm. A Lufkin step-up gear increases the 4670 rpm of the gas turbine power shaft to 9900 rpm as requested to drive the compressors.

The compressor components in contact with H_2S have been constructed in special material that withstands the corrosion effect of the gas (A 182 for the rotor).

Special care has been taken for the compressor shafts dry-gas sealing system. Turbine fuel gas will be used as buffering gas for the dry-gas seals. This gas will be compressed at about 4931 psi (340 bar), the inlet pressure level of the second compressor casing receiving also the seal leakages from the third casing.

This duty is carried out by two balanced-opposed reciprocating compressors Pignone 4HB/3 type, driven by a 469 hp (350 kW) electric motor, which in three phases compresses the buffer gas from 536 psi (37 bar) to approximately 5076 psi (350 bar). Two identical units are mounted on each barge, one of which is kept in standby.

The two barges are scheduled to begin their sea crossing to the Caspian site in September 2006, while the entire plant should be hooked up and begin operation in 2008. ■