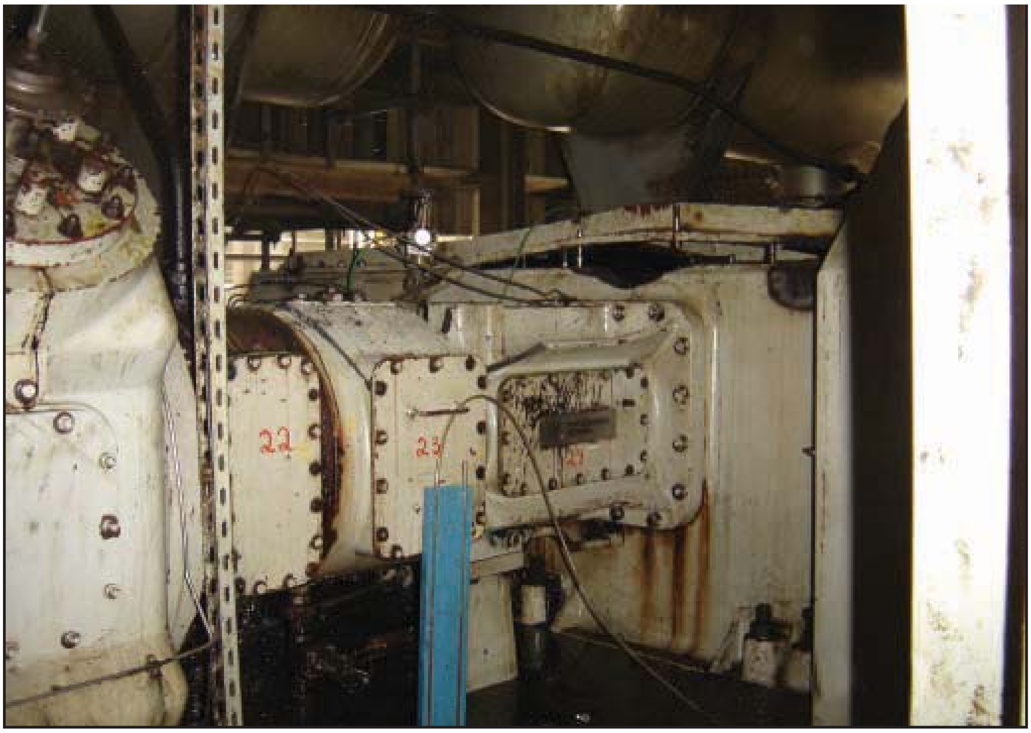

View of a distance piece of one of the two Mannesmann Demag, four-throw compressors, C-24101 A/B type 23B4G3/17, in the Petrobras oil shale plant in São Mateus do Sul. These compressors were instrumented with a Prognost NT monitoring system.

CONDITION MONITORING OF RECIPROCATING COMPRESSORS IN AN OIL SHALE PLANT

Prognost-NT System Monitors Compressors Installed in Petrobras' Oil Shale Plant in São Mateus do Sul

By Roberto Chellini

Often, reciprocating compressors are used to handle very dirty and corrosive gases that have a negative impact on the life of their components and can affect plant productivity. In such cases, installation of a condition monitoring system that enables operating the compressor safely by warning the operator in advance that maintenance is necessary, will increase the whole plant efficiency. This is why Petrobras (Petróleo Brasileiro S.A.) asked Prognost to install its Prognost-NT system on two Mannesmann Demag reciprocating compressors. These compressors were installed in 1987 in its oil shale plant in São Mateus do Sul to compress hydrogen sulfide. With the increase of energy prices, the use of oil shale to produce liquid fuels and hydrocarbon gases is becoming more popular.

Oil shale is a fine-grained sedimentary rock with significant amounts of kerogen, and is found around the world. This material can be burned directly as a low-grade fuel for power generation and heating purposes, or can be used as a raw material in the chemical and construction industries.

As of 2008, industry uses oil shale in Brazil, China, Estonia and to some extent in Germany, Israel and Russia. Several additional countries started assessing their reserves or had built experimental production plants, while others had phased out their oil shale industry. Petrobras' oil shale processing activities started as early as 1953 by developing Petrosix technology, extracting oil from oil shale. Now Petrobras operates two retorts, the largest of which processes 250 tons/hour of oil shale.

Owned and operated by Petrobras, Petrosix, Shale-Industrialization Business Unit, is operator of the world's largest surface oil shale pyrolysis retort with a 36 ft. (11 m) diameter vertical shaft kiln. It is located in São Mateus do Sul, some 75 mi. (120 km) from Curitiba and 119 mi. (180 km) from the Atlantic Ocean. Juliano Alexandre Lampert, machine maintenance engineer at São Mateus do Sul, and Carlos Roberto Chaves, automation engineer, explained how the whole process works. Petrosix developed its own process, which is one of five technologies commercially used for oil shale extraction. This is an externally generated hot gas technology for extracting oil from oil shale.

After mining, the shale is transported to a crusher, where it is reduced to particles, so-called lump shale. These fragments are then transported on a belt to the retort, a vertical cylindrical reactor, to be heated for pyrolysis up to about 932°F (500°C). This reaction produces the kerogen, an organic complex that decomposes when exposed to heat, and produces oil and gas. After pyrolysis, the oil is cooled to condense the vapor, and shale gases undergo another cleaning process for light oil extraction. The rest is then sent to the gas treatment unit, where fuel and liquefied petroleum gas (LPG) are produced and sulfur recovered. Part of the cooled retort gas is used as fuel in a tubular heater; part is heated in the heater pipes and circulated back to the middle of the retort as hot gas carrier for heating the oil shale feed. Part is circulated and enters into the bottom of the retort, where it cools down the hot shale coke. This part takes on heat and ascends into the pyrolysis

Cylinder side of one of the four-throw compressors compressing hydrogen sulfide in the Petrobras oil shale plant. These compressors were retrofitted with Prognost NT monitoring systems.

section for heating the oil shale feed as a supplementary heat source. The drawback of this process is that the potential heat of fixed carbon contained in the shale coke is not used. The compressor duty is to compress the excess gas derived from pyrolysis extraction from shale.

The plant is equipped with two Mannesmann Demag compressors, C-24101 A/B type 23B4G3/17. These are four-throw, balanced-opposed, reciprocating compressors with lubricated cylinders. The compressors are driven by 1408 hp (1050 kW) electric motors at a speed of 504 rpm.

The shale gas (hydrogen sulfide) is compressed in three stages. Between stages, extraction lines take out several condensates: fuel gas, a small percentage of naphtha, gas treatment with soda and DEA (H_2S extraction) and, at the end of the third stage, the LPG at about 230 psi (1550 kPa).

The compressor service is very demanding because the shale gas has high humidity and entrains many solid particles in suspension that are the cause of the majority of the problems and accidents with these machines. The main problems are caused by the deterioration of the sealing elements (packing leakages) and consequent H_2S attack on the internal compressor parts. These leakages led to possible condensate ingestion, and probable frequent condensate fog ingestion, as well as capacity loss because of valve obstruction. A few years after the installation of the machines, Mannesmann Demag stopped manufacturing reciprocating compressors, and Petrosix had no help to solve the problems. More recently, Neuman & Esser bought the rights to service Demag compressors and the German company made some recommendations, such as implementing temperature control of the cooling water, use of nitrogen as packing buffer gas, improvement of gas treatment to lower the amount of condensate and solid entrainment. These reciprocating compressors, however, did not have any devices allowing either predictive maintenance or early failure warning of the running parts.

In 2005, Prognost presented its Prognost-NT monitoring system expressly tailored for reciprocating compressor diagnostics. At São Mateus do Sul, the equipment operators had no experience in monitoring this type of machine. They only had a monitoring system installed on an old 9.4 hp (7 MW) Sulzer axial compressor installed in 1984, which allowed them to perform predictive maintenance.

Prognost specialists were able to explain to Lampert and Chaves the differences between a monitoring system installed on turbomachinery and one designed for reciprocating machines. They stressed the importance of continuously monitoring the machine and process conditions. This activity helped the machine failure diagnosis and/or operation out of the machine operating limits, giving support to the decision to intervene, leading and helping the problem analysis and, mainly providing machinery protection.

In the next step, Prognost formulated the specific monitoring objectives for the client. Finally, the whole system was purchased by Petrobras.