

# New Seals Solve Vibration Problem

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Sour gas compression trains are the heart of the sulfur removal process in sour crude oil refining. Today, sour gas removal becomes even more important due to higher emission standards and requirements for cleaner fuel. Therefore, the reliability and stable operation of machines in this process are essential in the overall refining processes of crude oil. Sulzer Hickham, a Sulzer Turbo Services company, solved stability problems in the sour gas compressors of a central Asian oil producer.

▶ Oil fields produce a mixture of oil, gas, and water. Oil and water are initially separated from the gas. Amine contacting processes remove free hydrogen sulfide already existing in the oil

or formed during the production of liquefied petroleum gas (LPG). Amines are a functional group formally derived from ammonia ( $\text{NH}_3$ ) by replacing one, two, or three hydrogen atoms with a

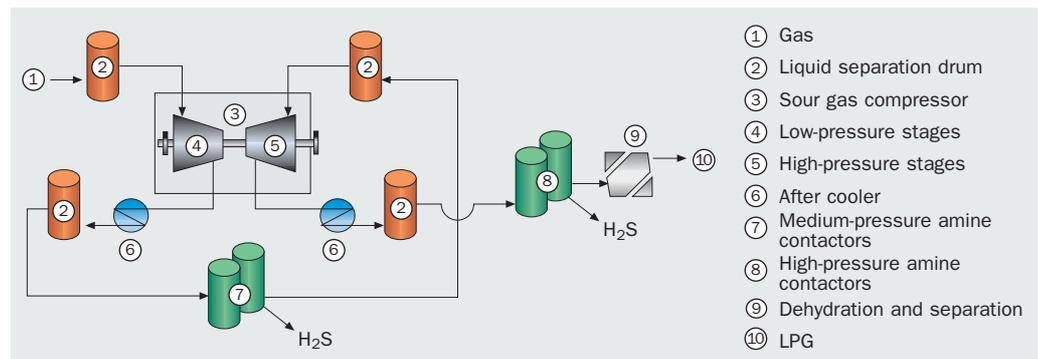
hydrocarbon group. Because they are basic amines can neutralize acids by forming corresponding salts.

### Removing Sulfur

In the sour gas removal process, after stabilization and separation of liquids, the gas is supplied to the low-pressure stages of the sour gas compressor (Fig. 1). The low-pressure compressor discharge is passed through an after-cooler and another liquid separation drum. During the course of refining liquefied petroleum gas, sulfur is removed by treating the sour gases through a compression cycle and by reaction with a reasonably strong base, usually an amine. The specific process in the central Asian refinery involves the use of three barrel compressors operating in parallel. The compressors are back-to-back designs with a low-pressure and a high-pressure stage. The gas is fed to medium-pressure amine contactors before repeating the cycle through the high-pressure stages of the compressor. The final sweet gas stream is then processed in gas dehydration and separation units and distributed as LPG.

### Vibration Problems in the Original Design

The process seals at either end of the rotor were originally designed



**1** Sulfur removal from sour gas is an essential step in the production of liquefied petroleum gas (LPG). Sulzer Hickham, a company of Sulzer Turbo Services, eliminated vibration problems in a sour gas compressor, thus improving the overall reliability of the refinery.

as oil film seals. Apart from keeping the sour gas from leaking to the atmosphere and contaminating the bearing lube oil, these seals provide some stiffness and damping to the machine.

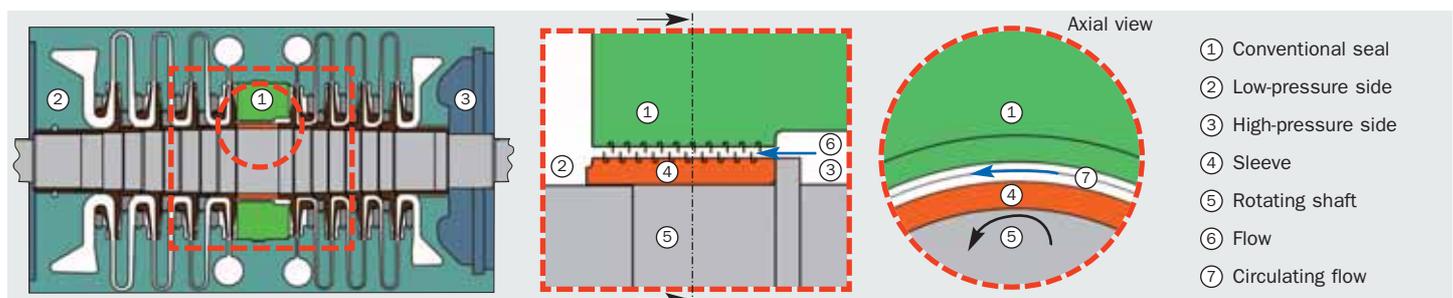
At the rotor midspan, a seal separates the low-pressure and the high-pressure sour gas stages. In the original configuration of the machine, this interstage seal was a labyrinth type seal.

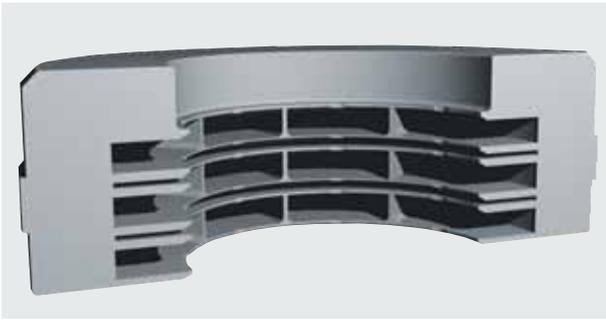
In many cases, labyrinth seals are the source of rotor instability problems. The flow characteristics in a labyrinth-type seal influence the rotordynamic behavior of the machine. Circulating flow in the labyrinths causes destabilizing cross-coupled forces, which affect the rotor stability (Fig. 2).

The original equipment manufacturer's (OEM) design of the

machine was marginally stable by a combination of the stabilizing damping influence from the oil film seals and the excitation by the labyrinth interstage seal. The problem arose when the oil seals were replaced with dry gas seals. Dry gas seals provide better sealing qualities and minimize the contamination of bearing lube oil. On the other hand, they are passive in the sense that they do not provide any contribution to the rotordynamic coefficients. Hence, by changing the seals, damping and stiffness were removed from the system.

**2** First bending mode oscillation amplitudes are maximum at the rotor midspan. The conventional seal located between high-pressure and low-pressure side was a source of instability, which lead to operational problems of the sour gas compressor.





**3** Sulzer Hickham solved the vibration problems with a novel seal type: the TAMseal, developed by Texas A&M University.

### Analysis Reveals Causes of Vibration

Following the startup of the modified machine, the operators recorded severe subsynchronous shaft vibration. The new configuration allowed the machine to vibrate at the first critical speed. The lack of damping from the oil film seals and the de-stabilizing effects of the interstage labyrinth seals were identified as the cause. Sulzer Hickham was contracted to perform a stability analysis and to provide a solution of the instability problem. The analysis confirmed that the lack of damping rendered the rotor's first bending mode unstable at operating speed. It additionally revealed the bearing maximum temperature to exceed 93 °C (200 °F)—as Babbitt starts to melt at around 110 °C (230 °F) this is too high for safe operation.

### Novel Seal Eliminates Vibration

The Sulzer Hickham engineers solved the problem by improving the bearing design. This included larger bronze-backed pads, ball and socket supports, and micro-babbitted bearing surfaces, allowing for more efficient heat removal and lower bearing temperatures.

The stability problem was corrected by replacing the interstage labyrinth seal with a TAMseal™ (Fig. 3). The TAMseal stability improvement comes from the ability to provide extra direct damping, and the reduction of cross-coupling by interrupting the circular flow through its cavity (Fig. 4). This solution provided the least impact on the existing geometry, since the new TAMseal fits within the envelope of the original labyrinth seal. The only modification to the rotor was the elimination of the j-strips on the interstage sleeve.

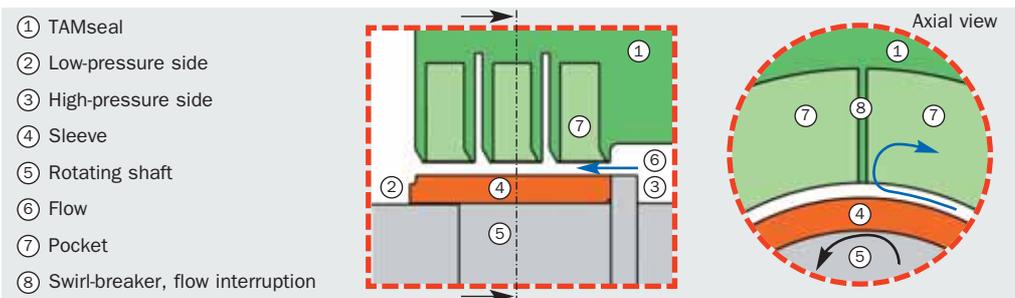
Once the modifications were finished, the compressor was started in an unloaded condition. The low-pressure stages were loaded, followed by the loading of the high-pressure stages. Throughout the startup of the machine, low vibration amplitudes were observed. The shaft vibrations remained low and at a constant am-

plitude, although the suction and discharge pressures were varied during the loading process. None of the previous indications of instability were observed.

### Increase of Mass Flow Planned

This solution provided not only an improvement of the machine's mechanical condition, but also reduced the downtime and emergency outages, and it increased reliability. Sulzer Hickham provided a sound, effective, and efficient solution to the instability problems of this compressor. Due to an increase in processing demand and vast natural resources available in central Asia, Sulzer Hickham is currently working on another engineering project to boost the capacity of the sour gas compressor trains in the same refinery. The new project of uprating the machines to increase the mass flow by 15% on the low-pressure stages and by 24% on the high-pressure stages is to be concluded in late 2005. ◀

**4** The TAMseal greatly improves the rotordynamic properties of the sour gas compressor. Swirl breakers interrupt the circumferential flow in the labyrinth gap and add damping in the center of the shaft.



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