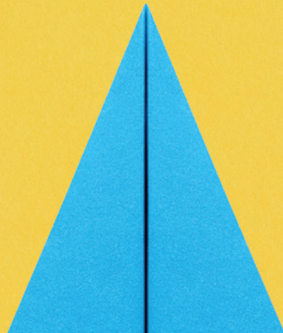


CHANGE THE SEAL,
MAXIMISE
THE YIELD

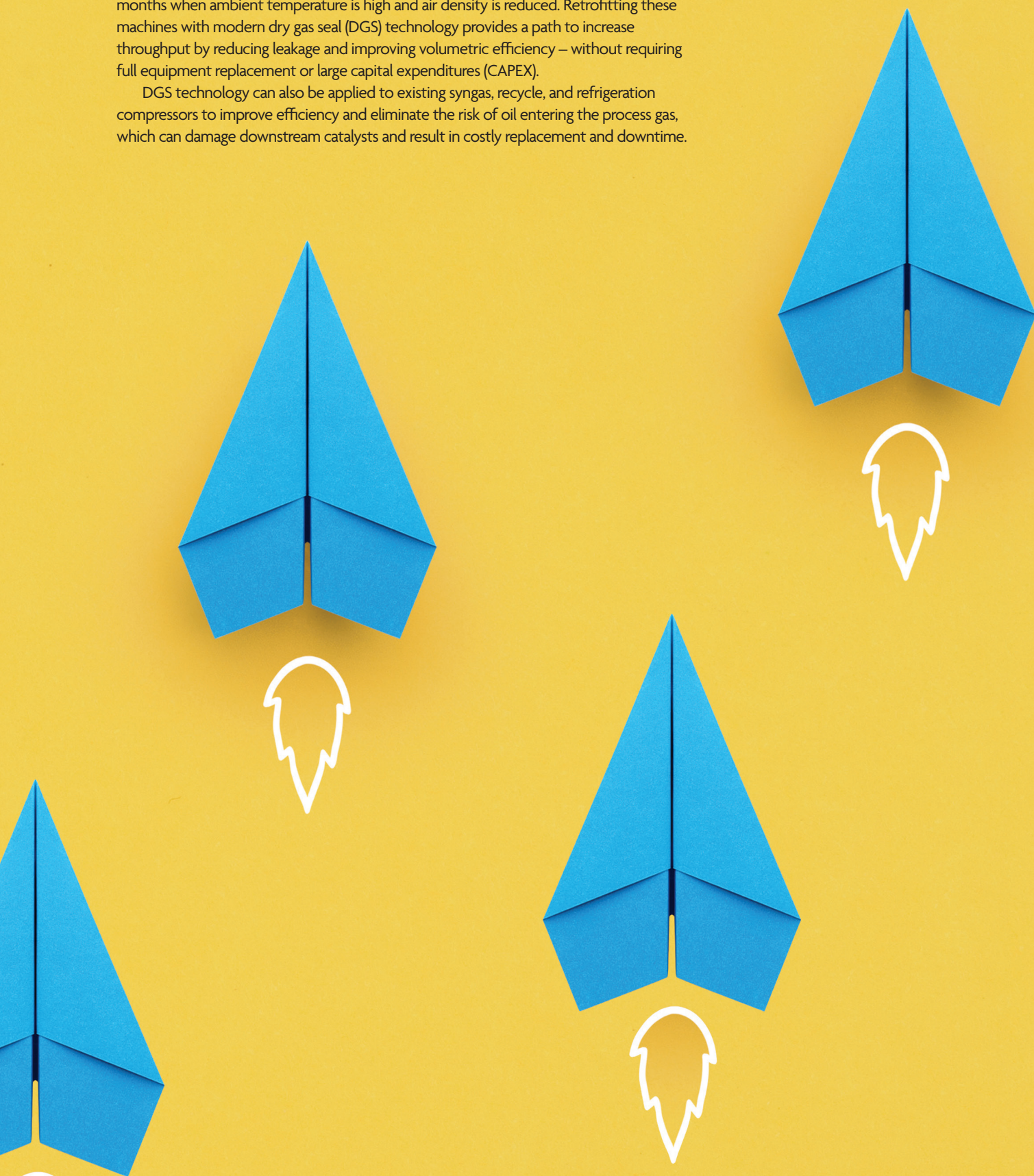


Randy Moore, Siemens Energy, USA, outlines the benefits of retrofitting ammonia plant compressors with modern dry gas seals.

As global demand for ammonia grows, producers are increasingly looking for ways to boost capacity and extend the life of their existing facilities. Steam turbines and compressors have become a logical target of modernisation initiatives, largely due to the significant impact they have on overall plant efficiency, production capacity, reliability, and operating costs (OPEX).

Particularly in older plants, the large, multi-stage compressors used to supply air to the secondary reformer can become a production bottleneck. This typically occurs in summer months when ambient temperature is high and air density is reduced. Retrofitting these machines with modern dry gas seal (DGS) technology provides a path to increase throughput by reducing leakage and improving volumetric efficiency – without requiring full equipment replacement or large capital expenditures (CAPEX).

DGS technology can also be applied to existing syngas, recycle, and refrigeration compressors to improve efficiency and eliminate the risk of oil entering the process gas, which can damage downstream catalysts and result in costly replacement and downtime.



Understanding compressor dynamics

The secondary reformer follows the primary reformer in the Haber-Bosch ammonia production process. Its main purpose is to introduce process air to supply nitrogen for ammonia synthesis, partially combust residual methane, hydrogen, and CO with oxygen from the air, and raise the gas temperature to complete methane reforming over a downstream catalyst.

Like the primary reformer, the secondary reformer operates at high pressure (typically 20 - 40 bar). To inject air into the environment, it must be compressed to a pressure higher than that of the reformer. Large, multi-stage centrifugal compressors are preferred for this application. With these machines, volumetric flow is primarily determined by rotational speed and impeller design. However, the mass flow (which is what matters for the chemical reactions in an ammonia plant) depends on the density of the air.

Consequently, in summer months when ambient temperature is high, it is not uncommon for ammonia production rates to decline, as there is reduced air mass

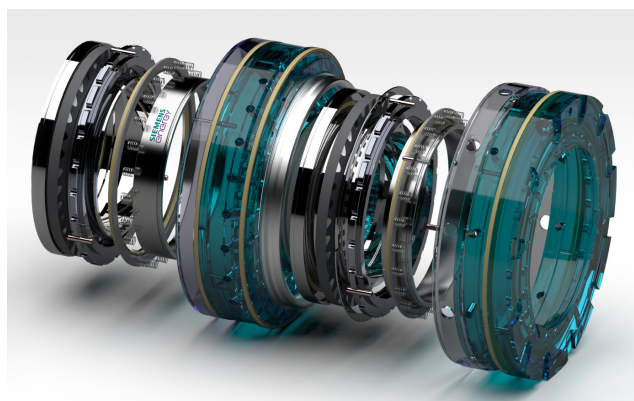


Figure 1. A Siemens Energy dry gas seal used on a centrifugal compressor.

Table 1. Estimated annual savings of DGS conversion on process compressors (illustrative example)

Benefit	Estimated annual savings	Notes
Catalyst replacement savings	- US\$250 000 - 5 million	Based on extending reformer catalyst life by two years. Could be much higher depending on actual catalyst lifespans.
Downtime reduction savings	- US\$3 million	Based on avoiding two days of unplanned downtime per year.
Maintenance savings	- US\$50 000	Reduced maintenance on the compressor itself due to DGS.
Total estimated savings	- US\$3.3 - 8.05 million	This is a conservative estimate. The actual benefits could be significantly higher in plants with frequent oil-related problems.

flow through the compressor. To compensate, some plants will bring in temporary compressors (often diesel or gas-driven). However, this increases operating expenses (e.g., cost of fuel, rental fees, maintenance, etc.) and Scope 1 emissions. It can also be challenging from a logistical standpoint.

Increasing production with DGS conversion

Seals installed around the rotating shaft in centrifugal compressors are used to prevent process gas from escaping where the shaft exits the compressor casing. Wet and/or labyrinth seals, which use circulating oil as a barrier, were used extensively from the 1960s to the 1990s and can be found on most of the compressors used in older ammonia plants in operation.

These seals operate reliably. However, they exhibit high leakage rates, which means that a portion of the air that the compressor draws in does not reach the discharge (- 0.5 - 2.0% of the compressor's flow per seal). This leakage results in wasted energy and lower mass air flow delivered to the secondary reformer.

DGSs are non-contacting mechanical seals that use a thin, controlled gas film (typically only a few microns thick) between a rotating seal face and a stationary mating face. During rotation, engineered grooves on the seal face generate hydrodynamic lift, separating the faces and creating a stable sealing gap.

Leakage with modern DGS technology is several orders of magnitude lower than conventional labyrinth seals. Therefore, for the same power input and speed, a compressor with a DGS will deliver a higher mass flow rate of air than one with labyrinth seals – translating directly into more ammonia production if there are no existing bottlenecks downstream.

DGSs also provide several additional advantages over wet seals, including:

- Lower maintenance: compressors with wet seals require ancillary systems and equipment to circulate and treat oil. These systems require maintenance. If the oil circulating system does fail, the compressor must be taken offline. Catalyst/oil changeouts can also contribute to outages. DGS systems, on the other hand, do not require any complex electro-mechanical systems for support. The result is fewer failure points and higher uptime.
- No parasitic power losses: oil circulation equipment, such as pumps, require power to run. Electricity consumption can be as high as 100 kWh, depending on the size of the compressor. This is an order of magnitude higher than the electrical load for a DGS system (around 5 - 6 kW).
- No oil ingress into the process: with dry gas seals, there is no risk of oil ingress across the seal into the process gas and the potential for damage to downstream catalysts is eliminated. This topic is discussed further in the article.

Quantifying the benefits

To illustrate the impact of a DGS conversion on the compressor supplying air to the secondary reformer, this

article examines a hypothetical ammonia plant with the following characteristics:

- 2500 tpd production rate.
- Operates 330 days a year.
- Air compressor delivering 150 000 kg/h of air to the secondary reformer.
- Process requires 6 kg of air per kg of ammonia produced (this is a simplified ratio; the actual value depends on the specific process conditions and stoichiometry).

In this scenario, a 1% increase in air mass flow through the compressor from the DGS conversion results in an additional 250 kg/h of ammonia production or ~ 6 tpd. This equates to an increase of 1980 tpy of ammonia.

In certain cases, it may also be advantageous to perform an aerodynamic upgrade (i.e., re-aero) of the compressor in conjunction with the DGS installation. The re-aero typically entails upgrading to new rotating and stationary parts (e.g., impellers, diffusers, etc.), without changes to the compressor casing, external process connections or existing footprint. Doing so can enable an additional 2 - 5% increase in ammonia production.

Siemens Energy has extensive experience performing these compressor modifications, along with various steam turbine upgrades within the turnaround window of a typical ammonia plant.

Applying a DGS to syngas and recycle compressors

DGS conversions can also be performed on syngas and recycle compressors. The primary benefit here is that it eliminates the risk of oil from wet seals entering the process gas.

Oil contamination, even in trace amounts, can have detrimental effects on the catalysts used throughout the ammonia synthesis process. Operators are cognisant of this problem and frequently employ multiple preventative measures, including demisters or coalescers,

activated carbon beds, guard beds, monitoring systems, etc. However, these are not 100% effective.

The mechanisms and consequences of oil ingress vary depending on the specific catalyst and the stage of the process where it occurs. The reforming catalyst and the low temperature shift (LTS) catalyst are particularly vulnerable. Over time, contamination leads to lower conversion rates, reduced efficiency, and potentially costly catalyst replacement.

Table 1 provides a conservative estimate of the potential financial savings by avoiding catalyst contamination with a DGS on process compressors.

Conclusion: small change, big impact

Significant financial savings are possible in ammonia plants by converting to a DGS on the:

- Air compressor for the secondary reformer.
- Syngas compressor(s).
- Recycle compressor(s).
- Refrigeration compressor(s).

Although every facility is unique in its design and boundary conditions, rough calculations show that potential annual financial savings can range from approximately US\$3.3 million (primarily from DGS efficiency gains and avoiding oil contamination) to over US\$40 million if the air compressor is a bottleneck and efficiency improvements enable large production increases.

It is important, when evaluating these types of strategic retrofits, for operators to engage with rotating equipment OEMs early on to determine what (if any) other upgrades may be possible given the compressor or steam turbine's existing components, age, recurring problems, etc. Doing so also helps to ensure that any potential execution risks are mitigated during the project, and that return on investment (ROI) is maximised. **WF**