Shell Catalysts & Technologies

CAPTURING CARBON DIOXIDE (CO_2) FROM REFINERY LOW- AND HIGH-PRESSURE STREAMS

WHITE PAPER

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ARE YOU A REFINER THAT IS...

...under pressure to meet your CO_2 emissions mandate?

...seeking ways to capture CO_2 from flue gas or high-pressure process streams?

...keen to apply proven, leading-edge carbon-capture technologies and benefit from valuable best practices in this area?

INTRODUCING SHELL CATALYSTS & TECHNOLOGIES

In 2019, in a highly customer-focused move, Shell combined its…

- refining and petrochemical technology licensor, **Shell Global Solutions**;
- refining catalysts company, **Criterion Catalysts & Technologies**; and
- petrochemical catalysts company, **CRI Catalyst Company**

…to create **Shell Catalysts & Technologies**.

The objective – to enable greater customer value. For more on our new organisation, please see page 11.

THE NEED FOR CARBON-CAPTURE TECHNOLOGIES

To help fulfil their responsibilities under the Paris agreement on climate change, governments around the world continue to introduce ever-tighter emissions controls, which leaves many refiners with a mandate to reduce their CO_2 emissions substantially.

For most businesses, a mosaic of solutions will be required, including energy-efficiency initiatives, fuel switching, process optimisation and using the best-available technology. Any serious ambitions to reduce a facility's carbon intensity are, however, likely to be spearheaded by carbon capture and storage (CCS). According to the International Energy Agency, this is a key technology for reducing CO_2 emissions in carbon-intensive industrial processes and offers one of the lowest-cost ways of doing so. In today's capital-constrained environment, however, one of the principal challenges that refiners may face is finding ways to do this economically.

This paper showcases two leading carbon-capture technologies that have established strong track records of performing this increasingly important function cost-effectively in a wide range of industries:

- **Shell's CANSOLV CO_2 Capture System** – for capturing CO_2 from low-pressure streams, including flue gas; and
- **Shell's ADIP ULTRA** technology for capturing CO_2 from high-pressure process streams.

Leveraging experience

Fortunately for refiners, theirs is not the first sector to have been charged with dramatically reducing the carbon intensity of their operations. Other energy-intensive sectors such as coal-fired power, oil sands and cement have already been down that path, and refiners can leverage their experience and the technologies they deployed to do the same.

Furthermore, through supporting Shell's diverse operations, Shell Catalysts & Technologies has already addressed many of the emission challenges that refineries worldwide are facing. We can share our technologies, operational experience and expertise to help refiners lower the carbon intensity of their operations.

SHELLL'S CANSOLV CO_2 CAPTURE SYSTEM – FOR CAPTURING CO_2 FROM LOW-PRESSURE STREAMS

Shell's CANSOLV CO_2 Capture System can capture up to 99% of the CO_2 from streams such as flue gases, off-gases and tail gases. As a low-pressure CO_2 capture technology, it is well suited for retrofitting to existing plants. It uses a regenerable solvent and a proprietary amine to capture the CO_2. The CO_2 is released as a pure stream that can be sold, sequestered or used in enhanced oil recovery (EOR).

In refiners' technical and economic evaluations for capturing CO_2 from flue gas, the CANSOLV CO_2 Capture System may emerge as the preferred option because of key features such as:

- **CO_2 purity.** The pure CO_2 product enables EOR, CCS or carbon capture and utilisation downstream of the plant.
- **adaptability.** The system is highly adaptable to a wide variety of industrial applications, gas flow rates and CO_2 concentrations from 3.5 to 25% and even higher. Licensed units treating gas flow rates from 11,000 to 685,000 Nm^3/h and CO_2 concentrations from 9 to 12.5% are in operation or under construction.
- **asset integrity.** The system has been designed for reliability through its highly flexible turndown capacity and improved resistance to oxidative and thermal degradation.
- **low waste.** The process uses a regenerable solvent so no direct waste by-products are generated, which can reduce project costs, as the effluents are minimal.
- **retrofit suitability.** As a standalone system, it is ideal for retrofit scenarios and greenfield projects.
- **low operating costs.** The system offers cutting-edge performance. For example, its low parasitic energy consumption, fast kinetics and extremely low volatility help to reduce the costs of operation and amine consumption.
- **track record.** The largest application designed to capture 1 Mt/y of CO_2 (see boxed text, Proof point: SaskPower).
- **potential for integrated sulphur dioxide (SO_2) removal.** It can be integrated with another technology, the CANSOLV SO_2 Scrubbing System, for near complete SO_2 removal and significant nitrogen dioxide removal (see boxed text, Proof point: SaskPower).

THE CANSOLV CO_2 CAPTURE SYSTEM CAN CAPTURE UP TO 99% OF THE CO_2 FROM STREAMS SUCH AS FLUE GASES, OFF-GASES AND TAIL GASES, AND IS WELL SUITED FOR RETROFITTING.

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PROCESS DESCRIPTION

Figure 1 shows the key steps for the CANSOLV CO_2 Capture System, which are as follows:

1. Feed gas is quenched and saturated in a circulated water pre-scrubber.
2. Gas contacts the lean amine solution in a countercurrent, mass-transfer, packed absorption column.
3. CO_2 is absorbed and the treated gas exits to atmosphere.
4. Midway along the column, partially loaded amine is removed from the tower, cooled and reintroduced over a layer of mass-transfer packing.
5. CO_2-rich amine from the absorption column is pumped through a lean–rich amine heat exchanger and then on to the regeneration column.
6. Rising, low-pressure, saturated steam in the column regenerates the lean amine solution. CO_2 is recovered as a pure, water-saturated product.
7. Lean amine is pumped from the stripper reboiler to the absorption column for reuse in capturing CO_2.
8. The CO_2 is directed to by-product management systems.

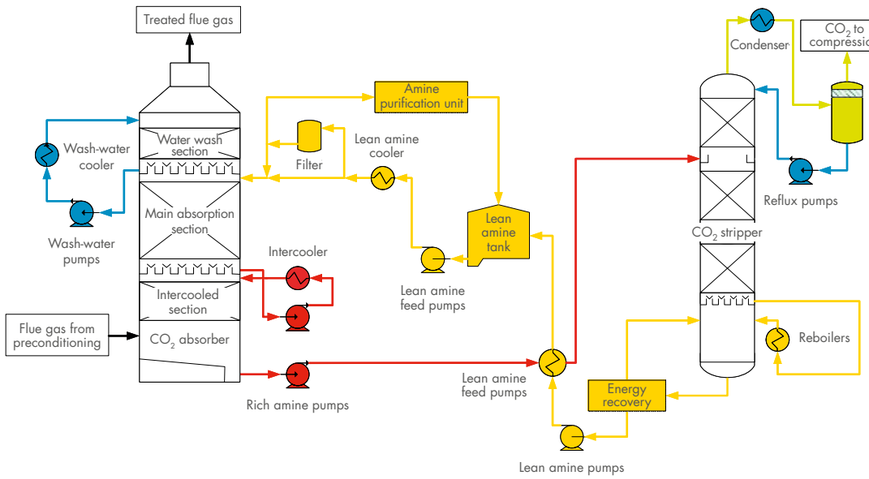

Figure 1: The CANSOLV CO_2 Capture System.

PROOF POINT: SASKPOWER

Situation

Because of tighter regulations, SaskPower needed to reduce both CO_2 and SO_2 emissions at its Boundary Dam power station in Saskatchewan, Canada. This six-unit, lignite-fired power plant is SaskPower's largest coal-fired power station and a significant source of power for the region.

Solution

After carefully evaluating a range of technical options, SaskPower chose to add a CANSOLV SO_2–CO_2 Integrated Capture System for combined carbon capture and flue gas desulphurisation. It opted to do this for the 150-MW Unit 3, which was due for refurbishment.

This involved adding a 55-m-tall CO_2 absorber, a 40-m-tall CO_2 stripper, a 31-m SO_2 absorber and a 17-m-tall SO_2 stripper.

Value delivered

The CO_2–SO_2 capture plant and its underlying chemistry have been proven to work. The plant remains in operation today, thereby enabling SaskPower to meet the strict Canadian regulations on CO_2 emissions.

The unit captures 1 Mt/y of CO_2. This CO_2 is compressed, transported through pipelines and used for EOR in nearby oilfields. Permanently stored in deep geological formations, the greenhouse gas will not contribute to climate change.

The SO_2 captured from the flue gas is converted to 60 t/d of a marketable by-product: sulphuric acid. Among its many other potential applications, the acid can be used as a feedstock for the local fertiliser industry.

SHELL'S ADIP ULTRA TECHNOLOGY – FOR CAPTURING CO_2 FROM HIGH-PRESSURE PROCESS STREAMS

In addition to capturing CO_2 from low-pressure flue gas, it is increasingly important for many refiners to capture CO_2 from high-pressure process streams such as those from hydrogen manufacturing units (HMU).

Here, Shell uses another amine-based technology – ADIP. Deployed at more than 500 Shell and non-Shell sites worldwide, Shell's ADIP technology has established an enviable track record for deep removal of CO_2 in the natural gas sector. It is also being increasingly applied in refining.

The latest generation is ADIP ULTRA, which uses an optimised solvent formulation and improved design based on years of operational lessons learned. With the latest-generation column internals (Shell Turbo Trays) this technology can easily achieve bulk removal thereby maximising CO_2 capture and meeting deep specifications for the treated gas while optimising both the capacity of the solvent and the regeneration duty (Figure 2).

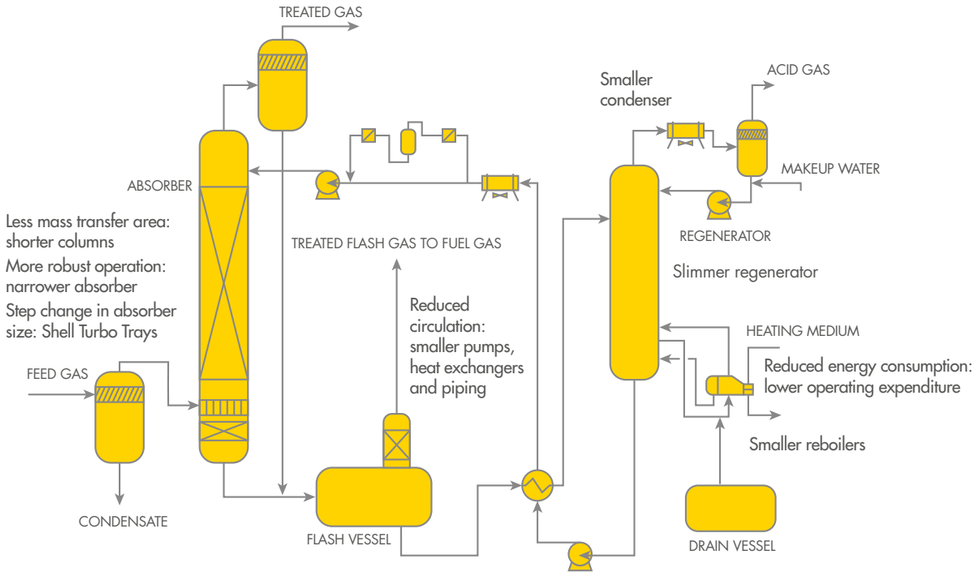

Figure 2: A typical ADIP ULTRA line-up, including key benefits.

Compared with using accelerated methyl diethanolamine (MDEA), ADIP ULTRA technology can help to:

- reduce capital costs by up to 30%, thereby increasing project net present value;
- lower regeneration energy requirements by up to 30%;
- capture up to 25% more CO_2, thereby enabling monetisation of difficult gas without capital investment; and
- provide operating stability, which enables operators to push the limits without operational instability.

ADIP technology's applications include the:

- removal of hydrogen sulphide and CO_2 from refinery and natural gas streams; and
- bulk removal of CO_2 from gas streams.

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PROOF POINT: QUEST

Situation

The Scotford upgrader at the Athabasca oil sands project in Alberta, Canada, processes mined bitumen by adding hydrogen in a process using heat and high pressure to break up the large hydrocarbon molecules and create synthetic crude oil.

It generates its own hydrogen at three on-site HMUs. However, this creates CO_2, so Shell launched the Quest project: the world's first commercial-scale CCS project for an oil sands operation.

Solution

Shell added CO_2 capture infrastructure adjacent to the HMUs. This uses amine absorbers and Shell's ADIP ULTRA technology to capture about 80% of the CO_2 from the HMUs' process gas streams. The captured CO_2 is then dehydrated and compressed, before being transported by pipeline approximately 75 km and injected into a layer of rock more than 2 km underground.

Value delivered

To date, the Quest project has successfully captured and sequestered more than 3 Mt of CO_2 from the Scotford upgrader and the facility has proven to be capable of capturing in excess of its nameplate capacity of 1 Mt/y of CO_2. Reducing CO_2 emissions by 1 Mt/y is equivalent to taking 175,000 North American cars off the road.

KEY TAKEAWAYS

LOW-PRESSURE APPLICATIONS

Shell's **CANSOLV CO_2 Capture System** is:

- **robust.** It can capture up to 99% of the CO_2 in exhaust gases and is highly adaptable and designed for reliability.
- **proven.** It has been deployed commercially: reference sites are capturing up to 1 Mt/y of CO_2.
- **cost-effective.** Its design features enable high CO_2 removal, low energy consumption and low waste generation.

Furthermore, the CO_2 that it releases is suitable for sale to the EOR and commodity markets, and for sequestration. The process is highly suitable for retrofitting and greenfield applications.

HIGH-PRESSURE APPLICATIONS

Shell's latest-generation **ADIP ULTRA** technology is:

- **robust.** It has established a track record of high levels of performance and reliability.
- **proven.** More than 500 sites have applied the technology to capture CO_2 from high-pressure process streams such as those from HMUs.
- **cost-effective.** It can help to reduce capital costs by up to 30% and lower regeneration energy requirements by up to 30%.[1]

ADIP is suitable for a wide range of high-pressure process streams such as those from HMUs and gasification units.

[1]Compared with accelerated MDEA technology.

ABOUT THE AUTHORS

Gary Bowerbank, Manager, Gas Processing Technology (Europe, Middle East, Africa and Russia), Shell Catalysts & Technologies, has more than 18 years' experience in Shell's gas processing business. He has supported various Shell and non-Shell up- and downstream projects, and has held several roles in a Shell joint-venture refinery. Gary graduated in 2001 from the University of Manchester Institute of Science and Technology, UK, with a master of engineering degree. He is a Chartered Engineer.

Farhang Abdollahi, Licensing Technology Manager, Gas Processing Technology (Europe, Middle East, Africa and Russia), Shell Catalysts & Technologies, joined Shell as the application lead for CANSOLV SO_2 and CO_2 projects, and continued as a licensing technology manager for gas processing and global CCS projects. He is a licensed Professional Engineer in Canada and brings over 20 years' of diverse experience within multiple segments of the oil and gas industry, mostly in oil refinery and gas separation and purification. Farhang graduated in chemical engineering from Tehran University, Iran, in 1999. He also has master of applied science degrees in petroleum engineering and management (Khazar University, Azerbaijan) and chemical engineering (University of Ottawa, Canada).

ABOUT SHELL CATALYSTS & TECHNOLOGIES

Shell Catalysts & Technologies supports Shell and non-Shell businesses by working with them to co-create integrated, customised solutions comprising licensed technologies, refining and petrochemical catalysts, and technical services.

It was formed by combining Shell Global Solutions, a technology licensor with a track record of delivering pioneering process schemes and innovative configurations; Criterion Catalysts & Technologies, the world's largest hydroprocessing catalyst supplier; and CRI Catalyst Company, a pioneer in the petrochemical catalyst sector.

It operates across the energy value chain, from upstream, gas processing and liquefied natural gas through to downstream refining and petrochemicals.

The fact that Shell Catalysts & Technologies supports Shell's global downstream network means that it has already addressed many of the challenges that its third-party customers face; the catalysts and technologies that it licenses have been developed in response to the same challenges.

For further information, please visit our website at **www.shell.com/ct**.