INTRODUCTION

Approximately one third of the world’s gas fields are highly contaminated and are classified according to their contaminants (H2S and CO2). Other contaminants such as COS (carbonyl sulphide), mercaptans and organic sulphides/disulphides are also present. Such contaminants need to be removed because of greenhouse gas concerns and stringent legal restrictions, as well as maintaining product specifications.

Plant operators face tough challenges in removing contaminants from their products, reducing emissions and meeting specifications.

Shell Global Solutions’ gas processing and sulphur recovery processes help meet these stringent requirements.

"The companies in which Royal Dutch Shell plc directly and indirectly owns investments are separate entities. In this presentation, the expression "Shell" is sometimes used for convenience where references are made to those entities individually or collectively. Likewise, the words "we", "us" and "our" are also used to refer to Shell companies in general or those who work for them. These expressions are also used where no useful purpose is served by identifying specific companies."
WHY SHELL?

Shell is a proven leader in research and development in contaminated gas, inventing and continuously improving some industry standard processes for the treatment of contaminated gas. Its new catalyst developments, evolving technology designs and smart processes focus on clients' requirements to meet commercial-sale goals and strict emission specifications.

- Shell's 100 years in business and more than 50 years developing and licensing proprietary gas-treating technologies
- Shell Global Solutions' combination of technical expertise with in-depth knowledge of and experience with upstream and downstream processes
- Use of Shell's technologies in more than 1,200 Shell-operated plants and 3rd party licensees globally
Shell Global Solutions offers a suite of technologies for treating contaminated feed streams before they reach downstream processes to help meet the most stringent environmental requirements.

The Acid Gas Removal licensed technologies, ADIP* and SULFINOL* processes remove carbon dioxide, hydrogen sulphide, mercaptans and carbonyl sulphide.

Sulphur Recovery Unit options such as Claus, SCOT*, Sulphur Degasser, THIOPAQ O&G*, SULFEROX* and CANSOLV* are selected based on emission regulations, product specifications and the volume of sulphur to be removed.

Please select one of the following categories or hit the next button to proceed to Acid Gas Removal:

- Acid Gas Removal
- Sulphur Recovery
- CANSOLV
- Associated Technologies

Names marked with an asterisk * are trade marks that are owned and used by companies of the Shell Group.
ACID GAS REMOVAL

This section will cover the following topics:

- ADIP & ADIP-X
- SULFINOL & SULFINOL-X
- HCN/COS Hydrolysis
ADIP* & ADIP-X*

ADIP technology dates back to the 1950s. Since then, more than 500 Shell operating facilities and licensees have applied the technology, and it has established a track record of high levels of performance and reliability. In 2000, Shell introduced ADIP-X technology, an enhanced version that uses accelerated reaction kinetics for better CO2 and COS removal. ADIP-X technology uses two amines, methyl diethanolamine (MDEA) as the main reactant and piperazine as the accelerator, and water.

FEATURES
- Faster CO2 and COS removal through enhanced reaction kinetics
- Higher loading capacity, reducing the solvent circulation rate and allowing smaller equipment
- Reduced steam requirements because of its lower solvent circulation rate and heat of reaction
- Very low hydrocarbon co-absorption
- Reduced solvent degradation, with no reclamation required

View the Case Study
View the Fact Sheets
- ADIP-X
- SOLVENT SWAPS
SULFINOL* & SULFINOL-X*

The SULFINOL-X solvent is designed to leverage the advantages of Sulfinol hybrid and accelerated methyl diethanolamine (MDEA) solvents in a single acid gas removal process. It employs two amines, MDEA as the main reactant and piperazine as the accelerator, along with sulfolane and water. This application offers performance advantages versus a conventional sour gas treating scenario.

FEATURES

- Faster CO2 and COS removal through enhanced reaction kinetics
- Quicker RSH removal from enhanced stability
- Higher loading capacity, which reduces the solvent circulation rate and allows smaller equipment
- Lower hydrocarbon co-absorption through decreased solubility
- Reduced solvent degradation, with no reclamation required
**HCN/COS HYDROLYSIS PROCESS**

The HCN/COS hydrolysis process catalytically converts hydrogen cyanide (HCN) and carbonyl sulphide (COS) to achieve bulk removal of HCN and COS to low levels.

The process prevents solvent degradation and corrosion in the downstream Acid Gas Removal unit.

HCN and COS are formed during gasification of vacuum residues, petcoke and coal.

**View the Fact Sheets**
- HCN/COS
- SYNGAS
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Thank you!
You have reached the end of this topic.

Would you like to:

- Choose another topic (Licensed Technologies)
- View Case Studies
- View Fact Sheets
- Start Over
SULPHUR RECOVERY

This section will cover the following topics:

- Claus Unit
- SCOT
- Sulpher Degassing
- THIOPAQ O&G
- SULFEROX
Shell Global Solutions can provide conventional Claus designs to give sulphur recovery efficiencies of up to 98%. The Claus unit design is based upon the experience of decades of operation across Shell and focuses on reliability and safety with high conversion.

FEATURES

- Reliability and safety enhancing features
- Offers up to 96-98% sulphur recovery
- Efficient burner design ensures effective combustion of ammonia and hydrocarbons
- Instrumented protective systems allowing simple, automated safe start-up and shutdown
- Applications include refining, natural gas and syngas

View the Fact Sheets

- SYNGAS
SHELL CLAUS OFF-GAS TREATING PROCESS (SCOT*)

Well-operated Claus tail gas units are required for today’s refineries and gas plants to meet strict environmental regulations.

The Shell Claus Off-gas Treating (SCOT) process catalytically converts the remaining sulphur dioxide in Claus tail gas to hydrogen sulphide. Hydrogen sulphide is then stripped from the tail gas and reprocessed.

FEATURES
- 99.5% sulphur recovery efficiency with a standard SCOT process
- More than 99.9% recovery with a low-sulphur SCOT
- Low-sulphur SCOT process produces <10 ppmv hydrogen sulphide in off-gas
- <10% turndown ratio
- Reduced CO emissions

View the Case Study
View the Fact Sheets
- SCOT
- SYNGAS
SHELL GLOBAL SOLUTIONS
TECHNOLOGY PORTFOLIO

SULPHUR DEGASSING

Shell Global Solutions’ sulphur degassing process reduces the hydrogen sulphide and hydrogen polysulphide content of Claus liquid sulphur from 250 to 300 ppmv down to less than 10 ppmv hydrogen sulphide.

In this process, the sulphur is circulated over a stripping column, open at the top and bottom, by bubbling air through the sulphur. Agitating the sulphur in this way releases the hydrogen sulphide. The whole system is located in a separate vessel or in the intermediate sulphur storage.

FEATURES
- No moving parts or catalysts
- Can be retrofitted into an existing pit or placed into a separate vessel
- Simple design
- Minimal operator attention required
- More than 120 units in operation
**THIOPAQ O&G**

The THIOPAQ O&G is a bio-desulphurisation process using the power of nature. It is attractive for sulphur removal in the range of 0.5-50 TPD.

A gas stream containing hydrogen sulphide contacts an aqueous soda solution in an absorber. The sulphite solution is converted by bacteria in bio-reactor into bio-sulphur.

**FEATURES**
- H2S removal efficiency >99.9 %
- Sulphur recovery about 95 %
- The hydrophilic nature of the bio-sulphur means no plugging or blocking problems
- Deep H2S removal, without need for tail-gas treating unit for off-gas
- Low CAPEX and OPEX
- Bio-sulphur is excellent for agricultural applications

View the Case Study

View the Fact Sheets
- THIOPAQ O&G
- SYNGAS
SULFEROX*

A regenerable liquid redox process for H2S abatement and sulphur recovery. The SULFEROX process is suited for handling gas streams that yield between 0.1 and 20 t of sulphur per day.

FEATURES

- High iron concentrations, small liquid flows
- Effective absorbers and contactors
- High flexibility and excellent turndown capacity
- Consistent operation
- A non-toxic sulphur product suitable for agricultural use (depending on the regulatory authorities)

More than 30 plants worldwide have applied the SULFEROX process.

View the Fact Sheets

- SULFEROX
- SYNGAS
SULFEROX

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More than 30 plants worldwide have applied the SULFEROX process.
This section will cover the following topics:

- S02 Scrubbing System
- C02 Capture System
- Integrated S02 & C02 System
CANSOLV SO2 SCRUBBING SYSTEM PROCESS

Unlock the value of sour and contaminated natural gas streams with CANSOLV TGT+ SO2 Scrubbing & Recycling System.

The CANSOLV reduces SO2 emissions from SRU Incinerators to World Bank Standards and less.

FEATURES
- Reduce the complexity of traditional Tail Gas Treating Line Ups when processing sour and contaminated natural gas streams.
- Reduce the overall CAPEX and OPEX of processing sour and contaminated natural gas streams.
- The captured SO2 can be converted into Sulphur or Sulphuric Acid, rather than being transferred to waste water plant or landfill.

View the Case Studies
- TREATING SOUR & CONTAMINATED NATURAL GAS
- SO2 CAPTURE FROM POWER PLANT

View the Fact Sheets
- CANSOLV S02
- CANSOLV TGT
Enable access to carbon credits from fossil fuels with the CANSOLV CO2 Scrubbing and Capture System.

The product is a pure, water-saturated CO2 gas which can be stored or used for Enhanced Oil Recovery and chemical synthesis.

FEATURES
- Enables bulk removal (90%) of the CO2 in the absorption tower
- Leading class low regeneration energy
- Elimination of high cost consumable reagents and associated transportation costs
- Reduced capital costs due to its high capacity and selectivity
- Minimal emission of effluents from the process
The CANSOLV SO2-CO2 Integrated Technology recovers SO2 and CO2 products, from post combustion gas streams, suitable for use in a variety of industries.

FEATURES
- Complete removal of SO2
- CO2 removal to 90%
- Minimal effluent as compared to traditional technologies
- Durable solvents in an oxidative environment
- Unique internal heat recovery resulting in best-in-class heat consumption

View the Case Study
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**THANK YOU!**
You have reached the end of this topic.

**Would you like to:**
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- View Case Studies
- View Fact Sheets
- Start Over
ASSOCIATED TECHNOLOGIES

This section will cover the following topics:

- Catalysts
- HiFi Trays
- Molecular Sieves
Criterion is an international company that supplies catalysts, process technologies and catalyst services for a wide range of process applications.

**Tail-Gas Treating Catalysts:**
Catalyst 099, for a catalytically promoted incineration process

Catalyst 534 ideally suited for the low pressure reduction reactor, and has demonstrated cycle lengths of more than 10 years in SCOT* units.

**FEATURES**
- Excellent physical strength, high surface area and good thermal stability with low pressure drop and metals loading optimized for tail gas treating. Physical strength and thermal stability safeguard it from the typical upsets encountered in tail gas treating.
Criterion is an international company that supplies catalysts, process technologies and catalyst services for a wide range of process applications.

**Tail-Gas Treating Catalysts:**
Catalyst 234 is a lower cost/fill alternative to catalyst 534. It is suitable for operations that historically have problems with carbon or soot formation or that have reduced catalyst cycles.

**FEATURES**
- High surface area, low pressure drop and excellent catalytic activity.

Catalyst 734 is the lowest-temperature option for the reduction and hydrolysis of the sulphur compounds in Claus tail gases.
The separation of gases from the liquid portions is an important process step. Shell Global Solutions’ alliance with Sulzer Chemtech provides operators with HiFi trays that offer the ability to handle large liquid loadings and can be equipped with different types of tray decks, including sieve holes, float valves and fixed valves, to increase throughput without making major changes to the plant.

- Most uniform flow path length and vapour distribution
- Self-balancing mechanism
- Minimum inactive zones and maximum bubbling area
- Lowest pressure drop and best mass-transfer efficiency at large liquid loadings
- Spacing as low as 300 mm
- Reduces entrainment and maximizes jet flood capacity

High performance column internals applied in all of our designs
Molecular sieves for drying and mercaptans removal

The molecular sieve design and service package helps gas and liquefied natural gas (LNG) plants to improve the operating costs, bed life, reliability and availability.

A combination of a molecular sieve and the SULFINOL process integrates dehydration and acid gas removal to focus on deep (organic) sulphur removal.

Well proven technology: ~ 30 molecular sieve units worldwide
Molecular sieves for drying and mercaptans removal

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SHELL GLOBAL SOLUTIONS
TECHNOLOGY PORTFOLIO

CASE STUDIES

- OMAN LNG - ADIP-X
- Resolving Foaming - SULFINOL-X
- Low Sulphur SCOT
- Low Temperature SCOT
- Bantry, Canada - THIOPAQ O&G
- Treating Sour & Contaminated Natural Gas - CANSOLV
- SO2 & CO2 Addressing the Environmental Challenge - CANSOLV
- SO2 Capture from Power Plant - CANSOLV
OMAN LNG - ADIP-X

Client: Oman LNG
Challenge: Solvent deterioration affected unit capacity.
Solution: After a thorough investigation, the plant switched to ADIP-X technology for the three trains.

RESULTS:
- Does not form degradation products
- Reduces the C6+ losses to the fuel gas system
- Increased condensate production by 2.5 TPD
- No solvent reclamation
- Reduction in operational costs of ~$70,000/year per train
RESOLVING FOAMING - SULFINOL-X

Plant description:
Two ARGUs, each treating approximately 190 MMSCFD of natural gas.

Feed gas:
4 mol% CO2 and 450 ppm H2S Treated gas specification are <50 ppm CO2 and <4 ppm H2S

Challenge
Plant was originally designed for and operated with SULFINOL-D. It began to experience significant foaming issues that caused capacity loss.

Solution:
Partial solvent swap to SULFINOL-X by adding MDEA and piperazine to the solvent.

Results:
This resolve the foaming problems and significantly increased the plant's gas processing capacity.
The Low-Sulphur (LS) SCOT shows significant benefits over conventional methods.

Revamp of SCOT absorber showed:
- Key technology for a very low sulphur emission (<10 ppm H2S) or savings on steam costs
- Ample commercial test data collected in recent years
- Less than 1% unscheduled downtime
- Proper design and operational knowledge crucial to prevent corrosion
LOW TEMPERATURE - SCOT

The data from a test programme at a Shell refinery illustrates the benefits of a low-temperature (LT) SCOT process.

- Energy efficient tail gas technology (~30-50% savings) with a very high sulphur recovery
- Commercialization of C734 catalyst
- Sharp design from extended kinetics knowledge based on a wide
- Optimizes sulphur train performance
- Applied at several sites over the last 8 years
BANTRY, CANADA - THIOPAQ O&G

A natural gas facility in Canada needed to remove a relatively small amount of sulphur from its gas streams. After evaluating conventional technologies, the operator chose the THIOPAQ O&G process for its economical and environmentally friendly solution.

- No flaring of hydrogen sulphide
- Remove hydrogen sulphide by selective biological conversion into elemental sulphur
- No upstream sour gas compression required
- No carbon or particulate filtration required
- No plugging/blocking challenges, due to hydrophilic biological sulphur
TREATING SOUR & CONTAMINATED NATURAL GAS

Ultra low SO2 emissions (5ppmv) required from SRU Tail Gas Treating Unit.
99.9% SRU Efficiency required.

Acid Gas contains > 1% of Sulphur as contaminants.

Maximum extraction of contaminants from natural gas by Sulfinol-X in AGRU
- Minimal CAPEX in Sales Gas Processing Units
- Flash gas can be incinerated > CANSOLV

Acid Gas from AGRU is lean (50% H2S <) and requires enrichment before SRU in AGEU
- Offgas can be incinerated > CANSOLV

Sulphur contaminated streams can be incinerated > CANSOLV

Gas Treating line up is 30% less CAPEX & 15% less OPEX than conventional processes
TREATING SOUR & CONTAMINATED
NATURAL GAS

Feed Gas

AGRU (Sulfinol-X)

MSU

NGL Extraction

Sales gas

Caustic Wash

Cansolv

Claus Unit

Degasser

Sulphur

SO₂ recycle

Sales gas

NGL

RSH in the Flash Gas & Off-Gases are now incinerated and captured by Cansolv

Deep RSH removal by Sulfinol-X to minimize SG Downstream Processing Units

Acid Gas (H₂S, CO₂, RSH, COS)

Flash Gas (+RSH)

AGEU off-gas (+RSH)

Incinerator + Quench

Sweep Gas

Quench Water (Sulphates)

Disulfide Oils

Other S streams can be Incinerated

Cansolv protects against slip (H₂S, RSH, COS)

Regeneration Gas (H₂O, RSH)

Other Streams can be Incinerated

Sulphur SO₂ recycle
**SO2 & CO2 - ADDRESSING THE ENVIRONMENTAL CHALLENGE**

Location: Coal-Fired Power Plant, Saskatchewan, Canada

Project: Integrated Carbon Capture and Sequestration (ICCS)

Project Outline:
- CO2 and SO2 flue gas capture from 150 MW power plant
- Capture capacity of 3,500 metric tons/day CO2
- 90% of CO2 removal and zero emissions of SO2
- SO2 to be converted to Sulphuric Acid
- CO2 use: Enhanced Oil Recovery

Start-up: Q3 2013
SO2 CAPTURE FROM POWER PLANT

Location: Coal-Fired Power Plant, China
Project: SO2 capture

Project Outline:
- SO2 flue gas capture from 240 MW power plant
- SO2 emissions less than 120ppmv
- Capture capacity of 350 metric tons/day Sulphuric Acid

Start-up: 2009
FACT SHEETS

- ADIP-X
- SULFINOL-X
- SCOT
- THIOPAQ O&G
- Sulferox
- HCN COS
- Syngas
- CansolvS02
- CansolvTGT
- Sulfinol-M
- Solvent Swaps
- Criterion
Gas development projects face growing challenges from resources containing increasing amounts of CO₂, tighter sales specifications and stricter environmental emission standards. At the same time, operators in the oil and gas industries are looking for solutions to debottleneck existing plants while reducing their operating costs and carbon footprint.

The Shell Global Solutions ADIP-X gas-treating process for CO₂ removal is an ideal solution for helping to meet these requirements in grassroots applications and solvent swap revamp situations.

ABOUT THE TECHNOLOGY
Shell Global Solutions has a long history of developing gas-treating processes; ADIP technology, for example, dates back to the 1950s. Since then, more than 500 Shell operating facilities and licensees have applied the technology, and it has established a track record of high levels of performance and reliability.

Moreover, the organisation continues to improve the technology, and in 2000 it introduced ADIP-X technology: an enhanced version that uses accelerated reaction kinetics for better CO₂ and COS removal from gases. A typical ADIP-X process line-up is shown in Figure 1.

SOLVENT DESCRIPTION
ADIP-X technology uses two amines, methyl diethanolamine (MDEA) as the main reactant and piperazine as the accelerator, and water.

ADIP®-X
For cost-effective, enhanced removal of carbon dioxide (CO₂)
Shell Global Solutions

AT A GLANCE
Customer driver: Growing development of natural gas resources with high CO₂ content; tighter product gas and liquefied natural gas (LNG) specifications; increasingly stringent emission regulations
Solution: ADIP-X process for application in LNG and natural gas production facilities, and refineries
Value delivered: Cost-effective enhanced removal of CO₂ and carbonyl sulphide (COS) along with the removal of hydrogen sulphide (H₂S), with low solvent-regeneration energy requirements
Proof point: More than 500 ADIP units designed and operated since 1959

Gas development projects face growing challenges from resources containing increasing amounts of CO₂, tighter sales specifications and stricter environmental emission standards. At the same time, operators in the oil and gas industries are looking for solutions to debottleneck existing plants while reducing their operating costs and carbon footprint.

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SOLVENT DESCRIPTION
ADIP-X technology uses two amines, methyl diethanolamine (MDEA) as the main reactant and piperazine as the accelerator, and water.
PROOF POINTS
To date, 10 facilities across the globe have implemented ADIP-X technology.

OMAN LNG
Oman LNG was suffering solvent deterioration that was affecting unit capacity. After a thorough investigation, it switched to ADIP-X technology and changed the solvent in each of its three trains in turn between 2006 and 2008.

The operator says the new solvent does not form degradation products and reduces the C6+ losses to the fuel gas system via the off-gas. As a result, it is recovering more C6+ hydrocarbons, which has enabled it to increase condensate production by 2.5 t/d. This increased condensate production is worth $180,000 a year per train. Not having to reclaim solvent off-site further reduces the company’s operational costs by about $70,000 a year per train.

In addition, there were environmental benefits gained because the ADIP-X solvent has about a 20% lower chemical content than the solvent it replaced.

BRUNEI LNG SDN BHD (BLNG)
ADIP-X has proved to be a robust, stable and very efficient CO₂ removal technology at BLNG’s Lumut, Malaysia, plant. BLNG introduced the technology when production forecasts indicated that the feed gas CO₂ content would increase to 1.25%, which was beyond the capacity of the plant’s existing CO₂ removal facilities.

ADIP-X was trialled and met all the criteria for success. The results show that the technology can treat feed gas containing up to 1.5% mol CO₂. Moreover, sourcing the solvent on which the ADIP-X formulation was based from the open market cut BLNG’s inventory costs by 40%.

ADIP-X SOLVENT CAN FACILITATE EFFICIENT AND STABLE OPERATIONS OWING TO ITS CHARACTERISTICS OF LOW LEVELS OF HYDROCARBON SOLUBILITY, FOAMING, FOULING, CORROSION AND DEGRADATION.

BUSINESS VALUE
The Shell Global Solutions ADIP-X gas-treating process cost-effectively treats gases with high CO₂ levels. Its advantages over conventional process line-ups include:

- faster CO₂ and COS removal through enhanced reaction kinetics;
- higher loading capacity, which reduces the solvent circulation rate and facilitates the use of smaller equipment;
- reduced steam requirements owing to its lower solvent circulation rate and heat of reaction;
- very low hydrocarbon co-absorption; and
- reduced solvent degradation, so reclamation is not required.

In addition, all the solvent chemicals can be sourced on the open market.

ADIP-X can treat feed gas containing up to 1.5% mol CO₂.

Have you considered how you can:

- effectively remove CO₂?
- effectively meet tighter gas specifications?
- increase the capacity of your facility?
- reduce the energy consumption of your facility?
- reduce your facility’s carbon footprint?
Gas development projects face growing challenges from increasingly sour resources, tighter sales specifications and stricter environmental emission standards. Meanwhile, operators are looking for solutions to debottleneck existing plants. The Sulfinol-X sour-gas-treating process can be an ideal solution in grassroots applications and solvent swap revamp situations.

ABOUT THE TECHNOLOGY
Shell Global Solutions has a long history of developing gas-treating processes; its first Sulfinol unit, for example, started up in 1964. More than 200 Shell facilities and licensees have applied the technology, and it has established a track record of high levels of performance and reliability. The organisation continues to improve the technology, and in 2004 it introduced Sulfinol-X, which employs a second-generation solvent that can lead to process line-up simplification (Figure 1).

SOLVENT DESCRIPTION
The Sulfinol-X solvent is designed to leverage the advantages of Sulfinol hybrid and accelerated methyl diethanolamine (MDEA) solvents in a single acid gas removal process. It employs two amines, MDEA as the main reactant and piperazine as the accelerator, along with sulfolane and water.

AT A GLANCE
Customer driver: Growing development of highly sour natural gas resources with hard to remove trace components; tighter product gas and liquefied natural gas (LNG) specifications; increasingly stringent emission regulations
Solution: Sulfinol-X sour gas treating process for application in LNG and natural gas production facilities
Value delivered: Cost-effective and simple one-step removal of hydrogen sulphide (H₂S), carbon dioxide (CO₂), carbonyl sulphide (COS), mercaptans (RSH) and other organic sulphur compounds
Proof point: More than 200 Sulfinol units designed and operated since 1964

A typical line-up for treating sour gas requires multiple process steps

A gas treating line-up employing Sulfinol-X technology is much simpler

Figure 1a: In a typical line-up for treating contaminated gas, multiple process steps are required for acid gas removal (top). H₂S, CO₂ and some COS are removed in the acid gas removal unit (AGRU); RSH and water are removed in the molecular sieve unit; and COS and other organic sulphides are dealt with in additional units downstream.

Figure 1b: A gas treating line-up employing Sulfinol-X technology (bottom) is simpler: H₂S, CO₂, RSH, COS and organic sulphides are removed in the AGRU, and the molecular sieve unit is needed only for dehydration. In this case, there is no need for a regeneration gas absorber or regenerator.
PROOF POINTS

Two facilities have already benefited from Sulfinol-X technology, and a new plant using it is scheduled to come online in the Middle East in 2011.

RESOLVING FOAMING, INCREASING CAPACITY

A plant that was originally designed for and operated with Sulfinol-D began to experience significant foaming issues that were causing a costly loss of capacity.

The plant had two AGRUs, each treating about 190 MMscf/d of natural gas. These units remove CO₂ and H₂S. The feed gas to the absorber had about 4 mol% CO₂ and 450 ppm H₂S, and the treated gas specification was <50 ppm CO₂ and <4 ppm H₂S.

Shell Global Solutions recommended adding MDEA and piperazine to the solvent. This was effectively a partial swap to Sulfinol-X solvent. This helped to resolve the foaming problems and significantly increased the plant’s gas processing capacity.

ENHANCING EFFICIENCY

A Sulfinol-D gas-treating plant was designed in 1966 for a Shell refinery in the USA. CO₂ was removed from 75 MMscf/d of hydrogen upstream of a methanator.

To lower the solvent circulation rate and eliminate diisopropanolamine (DIPA)–oxazolidone reclamation, the amine used in the solvent was switched from DIPA to an MDEA–piperazine mixture between 2008 and 2010. As the heat rates to the reboiler are constrained by limited regenerator overhead cooling, sulfolane is used to manage the lean loading of the solvent at low heat input.

The solvent swap, first to aqueous MDEA–piperazine and then to Sulfinol-X, therefore offers improved deep removal of CO₂ (lower solvent circulation) and improved waste management (no oxazolidone formation). The feed gas to the absorber has about 17 mol% CO₂ whereas the treated gas typically has <50 ppmv CO₂ since the changeover to Sulfinol-X.

BUSINESS VALUE

The application of Sulfinol-X technology offers many performance advantages compared with a conventional scheme for treating sour gas. Crucially, the treating line-up is simpler and it enables all-in-one removal of contaminants, which can help to reduce capital and operating expenditure.

Other advantages include:
- faster CO₂ and COS removal through enhanced reaction kinetics;
- quicker RSH removal owing to enhanced solubility;
- higher loading capacity, which reduces the solvent circulation rate and facilitates the use of smaller equipment;
- reduced steam requirements owing to its lower solvent circulation rate and heat of reaction;
- lower hydrocarbon co-absorption through decreased solubility; and
- reduced solvent degradation, so reclamation is not required.

In addition, all the solvent chemicals can be sourced on the open market.

HAVE YOU CONSIDERED HOW YOU CAN
- cost-effectively meet your facility’s environmental mandate?
- minimise operator requirements?
- reduce the use of expensive chemicals?

Sulfinol is a Shell trademark.

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

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Oil and gas operators face growing challenges from increasingly stringent environmental regulations on sulphur emissions. The current World Bank standards prescribe that refineries should emit no more than 150 mg/Nm³ sulphur dioxide (SO₂). Emissions restrictions on carbon monoxide (CO) are also imminent.

At the same time, newly found oil and gas fields tend to contain higher levels of sulphur species and other contaminants. In combination with the tightening of product specifications, this results in increasing loads of contaminants, such as ammonia and organic sulphur components, in the feed to the Claus unit.

As Claus-based units are limited to sulphur recovery rates of up to 96–98%, tail-gas treating is required to reach higher levels.

**PROCESS DESCRIPTION**

As shown in Figure 1, the process has three sections:

1. a reduction reactor, in which all the sulphur compounds present in the Claus tail gas are converted to hydrogen sulphide (H₂S)
2. a cooling/quench section, where the reactor off-gas is cooled and the water is condensed
3. an absorption section, in which H₂S is selectively absorbed by an amine solution. The loaded solvent is regenerated and the acid gas released is recycled to the inlet of the Claus unit.

SCOT units can be designed with a dedicated amine regenerator or with a shared amine system.

**ABOUT THE TECHNOLOGY**

Shell Global Solutions offers the following optimised SCOT designs, which have been developed to help meet specific requirements.

### Super-SCOT

This is a two stage-regeneration design applied to integrated amine systems to meet SCOT off-gas specifications of as low as 30-ppmv H₂S.
Low-Sulphur (LS-) SCOT
This is the key technology for very low sulphur emissions (as low as 10-ppmv H₂S or 50-ppmv total sulphur). A small concentration of an inexpensive additive is added to the amine. This improves solvent regeneration and solvent leanness. Alternatively, LS-SCOT can be used to reduce the steam requirements and keep the H₂S emission level constant.

Low-Temperature (LT-) SCOT
To save fuel, minimise carbon dioxide (CO₂) emissions and maximise catalyst cycle length, a hydrogenation catalyst with increased activity is used to enable the tail-gas treating reactor to operate at lower inlet temperatures.

Mercaptan-destruction SCOT
To remove mercaptans, two parallel hydrogenation catalyst beds are employed: one for the main Claus tail gas and one for mercaptan-containing off-gases. This line-up is typically applied in gas plants handling complex contaminated gas mixtures.

CO-SCOT
Unlike other tail-gas processes, CO-SCOT also reduces the level of CO in the tail gas.

Have you considered how you can
- effectively meet the future regulations for SO₂ and CO emissions for your new or existing tail-gas treating unit?
- cut the operating cost of your tail-gas treating unit?

BUSINESS VALUE
SCOT technology enables very high levels of sulphur recovery and very low levels of SO₂ emissions to be achieved. Consequently, it is a key process for fulfilling increasingly stringent emission specifications, including the most stringent World Bank standards.

Other benefits include:
- high flexibility – The process can operate over a wide range of sulphur intakes. A turndown ratio of less than 10% of design throughput is achievable.
- low maintenance requirements – The unit requires little operational attention.
- excellent reliability – Less than 1% unscheduled downtime has been achieved in Shell-advised units.
- reduced CO emissions.
- good tolerance to incomplete ammonia destruction in the upstream Claus unit.
- no troublesome secondary waste streams.
The THIOPAQ O&G process is an environmentally friendly desulphurisation process for removing H₂S and recovering it as elemental sulphur from sour gas streams. The unique aspect of the process is that it utilises naturally occurring bacteria to oxidise H₂S to elemental sulphur, which can be used for fertiliser production, amongst other options.

The process was originally marketed by Paques BV for the treatment of biogas, which is produced by the anaerobic digestion of waste water. Co-operation with Shell Global Solutions led to further development of the process for application at high pressure in oil and gas environments. It can be economically applied to projects recovering up to 150 t/d of sulphur.

For the natural gas and petrochemical environments, the process is licensed by Paqell BV, a joint-venture company of Shell Global Solutions International BV and Paques BV.

**ABOUT THE TECHNOLOGY**

- **First commercial unit built for biogas desulphurisation in 1993 in the Netherlands; over 100 applications since then**
- **First commercial THIOPAQ O&G unit for natural gas built in Canada in 2002**
- **Since 2002, eight commercial reference units in the oil and gas industry have been established. Seven units are at the start-up, construction or design phase.**

**PROCESS DESCRIPTION**

The process integrates gas purification with sulphur recovery in one unit. The sour gas is first scrubbed with a mildly alkaline sodium hydroxide (NaOH) solution. This solution absorbs the H₂S to form sodium bisulphide, and sweet gas exits the contactor.

**THIOPAQ O&G TECHNOLOGY WAS ACCLAIMED IN THE PRESTIGIOUS IChemE INNOVATION AND EXCELLENCE AWARDS OF 2007 BY WINNING THE SELLAFIELD AWARD FOR ENGINEERING EXCELLENCE.**
Depending on the sour gas pressure, the bisulphide-rich solution is routed to a flash vessel or directly to the bioreactor, which operates at atmospheric pressure and ambient temperature, where a controlled amount of air is introduced (see Figure 1). Naturally occurring bacteria (*Thiobacillus* spp.) consume the bisulphide ions and excrete elemental sulphur, which is separated from the circulating solution. The process produces hydroxide ions that effectively regenerate the caustic solution used in the absorption step, which reduces the consumption of chemicals.

The process can replace a complete train of H$_2$S removal and sulphur recovery installations, see Figure 2. Another option is to retain the amine unit (for example, when carbon dioxide removal is also required) and replace only the sulphur recovery unit (SRU), the tail-gas treating unit (TGTU), the degasser and, possibly, the incinerator by a single THIOPAQ O&G unit.

### PERFORMANCE DATA
- Sulphur production: 0.05–150 t/d
- H$_2$S concentration in sour gas: up to 100%
- H$_2$S removal efficiency: >99.9%
- H$_2$S in treated gas (high pressure >4 bar): <4 ppmv
- H$_2$S in treated gas (low pressure <4 bar): <25 ppmv

### BUSINESS VALUE
THIOPAQ O&G technology offers a series of benefits:
- **Reduced operating costs.** The expensive chemicals required for liquid redox processes are not necessary; only sodium hydroxide and nutrients are required.
- **Reduced capital expenditure.** The process operates at ambient temperature and does not require equipment such as burners and reboilers. The regeneration and sulphur recovery section always operates at ambient pressure and temperature.
- **Ease of operation.** The biologically produced sulphur is hydrophilic. This feature eliminates plugging problems, so minimal operator attention is required.
- **Safety.** An additional feature of the process is that there is no free H$_2$S (no acid gas) after the bioreactor.

### HAVE YOU CONSIDERED HOW YOU CAN
- Cost-effectively meet your facility’s environmental mandate?
- Minimise operator requirements?
- Reduce the use of expensive chemicals?

For further information, please visit the websites at www.shell.com/globalsolutions and www.paqell.nl.

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ABOUT THE TECHNOLOGY

There are numerous methods for reducing hydrogen sulphide in process streams and each has a specific application range (Figure 1). Extensive pilot plant testing and commercial operations show that the SulFerox process is very well suited for handling gas streams that yield between 0.1 and 20 t/d of sulphur.

PROCESS DESCRIPTION

SulFerox is a redox-based process that converts the hydrogen sulphide in sour gas to elemental sulphur through reaction with aqueous ferric iron. The process forms solid sulphur particles that are easily filtered out.

There are three steps in the process: absorption, regeneration and sulphur recovery. During absorption, the sour gas stream comes into contact with a liquid containing soluble iron (III), and hydrogen sulphide is selectively oxidised to form elemental sulphur.

Regeneration involves re-oxidation of the iron (II) to maintain a supply of active iron (III). To maximise sulphur recovery, the elemental sulphur formed in the first reaction is concentrated in a surge tank and then filtered out. The filtrate is returned to the process for maximum ferric iron solution recovery.

In most cases, filtration and melting produce yellow sulphur of a quality comparable to that of conventional Claus unit sulphur.

ACID-GAS TREATING

Acid-gas treating has traditionally required an amine plant to remove hydrogen sulphide and a Claus unit to convert the concentrated hydrogen sulphide stream to sulphur. The SulFerox process is an alternative to these steps and consequently offers substantial savings in capital and operating costs by removing hydrogen sulphide directly from gas streams and converting it to elemental sulphur.

The SulFerox process was first applied in 1990, and has since been used worldwide for applications including:

- refinery hydrotreater off-gas;
- amine off-gas;
- refinery process streams;
- coke oven gas;
- primary natural gas treating; and
- associated gas (onshore and offshore).

Figure 1: Hydrogen sulphide processing selection chart.
PROOF POINTS

To date, more than 30 plants worldwide have applied the SulFerox process to produce sulphur at outputs ranging from 0.1 to 20 t/d.

OIL AND GAS, OFFSHORE USA

The SulFerox process is very well suited for gas processing on an offshore platform where the key requirements for process installations are a small footprint and low weight. The first offshore SulFerox plant was installed and started up on a platform off the coast of California. The operator uses the SulFerox process to treat natural gas that is fed into the unit at 150 psig and has a hydrogen sulphide content of 1.2 vol%. The plant produces about 3 t/d of sulphur.

SILICON CARBIDE MANUFACTURING, USA

A North American silicon carbide manufacturer uses the SulFerox process to remove hydrogen sulphide from by-product waste gas and convert it to elemental sulphur. The resultant sulphur-free gas is suitable for use as a fuel source. The process equipment comprises a particulate cleaning station, desulphurisation units, a compression unit, a dehydration unit and a gas pipeline to the power plant.

BUSINESS VALUE

The Shell Global Solutions SulFerox process offers a flexible solution for sour-gas treatment. Operating in the 0.1–20 t/d sulphur range, the SulFerox process requires less process equipment and energy to operate than the amine–Claus alternative (Figure 2).

Removing contaminants from sour streams helps to support efficient operations and maximise the value of the product slate. SulFerox is a flexible system that offers several advantages over conventional systems:

■ reduced capital expenditure and lower operating costs;
■ flexibility to cope with changes in gas volume and hydrogen sulphide content;
■ effective treatment of gases with very low hydrogen sulphide concentrations;
■ non-toxic elemental sulphur product; and
■ suitability for low- and high-pressure (<450-psig) applications.

SulFerox is a Shell trademark.

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GS33760911 Am(A)
HYDROGEN CYANIDE (HCN) AND CARBONYL SULPHIDE (COS) HYDROLYSIS
Cost-effective catalytic conversion for the treatment of synthesis gas (syngas)

Shell Global Solutions

AT A GLANCE

Customer driver: Conventional amine treating solvents are unable to remove COS from syngas and off-gas streams, and HCN causes severe degradation of the amine solvent.

Solution: A hydrolysis process that catalytically converts HCN and COS

Value delivered: Cost-effective removal of HCN and COS, more selective solvent use and reduced solvent degradation

Proof point: Four reference units worldwide

Gasification processes produce syngas that is composed mainly of hydrogen and carbon monoxide (CO). However, contaminants such as COS and HCN are also formed. Failure to remove HCN leads to amine degradation in the downstream amine unit, and COS compromises the total sulphur specification of the treated gas. Deep removal of both these contaminants is impossible using conventional amine treating solvents.

ABOUT THE TECHNOLOGY

The catalytic conversion of HCN and COS is a cost-effective process for reducing the harmful effects of these components in gas streams. This hydrolysis technology has two main fields of application:

- syngas treatment upstream of an amine unit for coal or oil gasification processes; and
- syngas treatment where the presence of HCN or COS is unacceptable to downstream processing units such as gas to liquid processes.

PROCEDURE DESCRIPTION

The HCN and COS in syngas are converted in a fixed-bed reactor filled with a catalyst system according to:

\[
\text{HCN} + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{CO} \\
\text{COS} + \text{H}_2\text{O} \rightarrow \text{H}_2\text{O} + \text{CO}_2
\]

The syngas is fed to the guard reactor where partial conversion of HCN and COS takes place. The guard reactor’s primary function is to collect soot and debris on top of the bed and protect the main reactor, where full conversion of HCN and COS occurs.

After passing through the catalyst beds, the syngas is cooled and the water is knocked out. Most of the ammonia (\text{NH}_3), traces of formate and some of the carbon dioxide (\text{CO}_2) and hydrogen sulphide (\text{H}_2\text{S}) will dissolve in the knocked-out water, which is then typically routed to a sour water stripper or other water treating facility.

HCN/COS HYDROLYSIS ENABLES MORE SELECTIVE SOLVENT USE AND CAN HELP TO REDUCE SOLVENT DEGRADATION.
PROOF POINTS

WILLEM-ALEXANDER POWER PLANT
The acid gas removal unit at Nuon’s integrated gasification combined-cycle (IGCC) showpiece power station in Buggenum, the Netherlands, applies HCN/COS hydrolysis and the Sulfinol® process to cut the syngas’s sulphur content to less than 20 ppmv.

SANNAZZARO REFINERY
Eni’s refinery near Pavia, Italy, creates syngas from heavy residues, which it supplies to the nearby EniPower power plant. The plant features cutting-edge technologies, including Shell Global Solutions residue gasification and HCN/COS hydrolysis technologies.

BUSINESS VALUE
Shell Global Solutions HCN/COS hydrolysis technology cost-effectively removes HCN and COS. Catalytic conversion creates NH₃ and H₂S, which can be removed easily in downstream processes.

In addition, HCN/COS hydrolysis enables more selective solvent use and can help to reduce solvent degradation.

Our services include:
- basis of design;
- proprietary catalysts;
- process warranties;
- operating manuals;
- performance monitoring methods;
- plant optimisation; and
- advice on unit operation.

Catalysts can be sourced through CRI/Criterion Inc., the global catalyst technology company of the Shell Group.

HIGH-PERFORMANCE GAS-TREATING SOLUTIONS SERIES

HAVE YOU CONSIDERED HOW YOU CAN
- cost-effectively remove HCN and COS from gas streams?
- enable more selective solvent use?
- reduce solvent degradation?

REFERENCES

<table>
<thead>
<tr>
<th>Client Location</th>
<th>Capacity, x10⁶ Nm³/d</th>
<th>Feedstock</th>
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<tr>
<td>Urea plant Australia</td>
<td>9.4</td>
<td>Coal</td>
</tr>
<tr>
<td>IGCC power plant Korea</td>
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<tr>
<td>Eni refinery Sannazzaro, Italy</td>
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<tr>
<td>Nuon IGCC power plant Buggenum, the Netherlands</td>
<td>3.4</td>
<td>Coal</td>
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</tbody>
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GS33801211 En(A)
Raw syngas often requires further processing for it to meet product specifications, as the concentrations of components such as carbon dioxide (CO₂), hydrogen sulphide (H₂S), carbonyl sulphide (COS), ammonia (NH₃) and hydrogen cyanide (HCN) are functions of the coal or residue feedstock.

Shell Global Solutions offers a wide selection of licensed technologies for syngas treating and sulphur removal to help meet product specifications (Figure 1). These can be licensed as standalone technologies; however, when supplied as an integrated solution with Shell gasification technology, additional value can be unlocked, as this helps to maximise heat recovery and the process’s energy efficiency.

### HYDROLYSIS AND ACID-GAS REMOVAL TECHNOLOGIES

Shell Global Solutions licenses the following technologies for hydrolysis and acid-gas removal.

**HCN/COS hydrolysis**

This removes HCN and COS. Catalytic conversion creates NH₃ and H₂S, which can be removed easily in downstream processes. The catalyst can be sourced through Shell’s catalyst company, CRI Catalyst Company. This process efficiently removes both HCN and COS.

**Sulfinol®**

This is a regenerative process for the removal of acidic components from a gas stream. What distinguishes the Sulfinol process from other absorption processes is its use of a mixture of solvents, which enables it to behave as both a chemical and a physical absorption process. The solvent is composed of Sulfolane, di-isopropanolamine or methyldiethanolamine and water. The acid-gas loading of the solvent is higher and the energy required for its regeneration is lower than those of purely chemical solvents. Product specifications can be met more easily than with purely physical solvents, and co-absorption of syngas is low.
Acid Gas Enrichment
This solvent-based process takes an acid gas stream containing $\text{H}_2\text{S}$, $\text{CO}_2$ and other compounds, and converts it into an enriched $\text{H}_2\text{S}$-containing acid-gas stream and a clean $\text{CO}_2$ stream. The requirement for the enrichment step depends on the $\text{H}_2\text{S}$ to $\text{CO}_2$ ratio and is, therefore, influenced by both the feedstock (sulphur content) and the gasification technology ($\text{CO}_2$) content.

ADIP®
This regenerative process uses an aqueous solution of amines to remove $\text{H}_2\text{S}$ and $\text{CO}_2$ from gases and liquids. Depending on the formulation of the solvent, it can be designed to be selective for $\text{H}_2\text{S}$ over $\text{CO}_2$ to achieve low $\text{H}_2\text{S}$ concentrations in the treated syngas in the presence of $\text{CO}_2$, or it can be designed for efficient $\text{CO}_2$ removal.

SULPHUR REMOVAL AND RECOVERY TECHNOLOGIES
Shell Global Solutions licenses technologies that convert the $\text{H}_2\text{S}$ in the gas streams from the amine regeneration and sour water stripper units to elemental sulphur.

Claus
This thermal and catalytic process converts gaseous $\text{H}_2\text{S}$ into elemental sulphur. A well-designed and operated Claus sulphur recovery plant can achieve overall conversion levels of at least 98%. The remaining gas separated from the last condenser, the tail gas, is either burned in an incinerator or further desulphurised in a tail-gas treatment unit.

SCOT®
The Shell Claus off-gas treating (SCOT) process has been developed to remove sulphur compounds from Claus tail gas to enhance sulphur recovery and comply with ever-increasingly stringent emission regulations. The tail-gas treating unit can be designed to meet World Bank emission standards and achieve sulphur recovery efficiency levels of 99.98% or higher.

HAVE YOU CONSIDERED HOW YOU CAN
- effectively remove HCN, COS, $\text{H}_2\text{S}$ and $\text{CO}_2$?
- minimise the capital expenditure and operating costs for sour-gas processing?
- obtain flexibility in managing varying syngas specifications?

PROOF POINTS
WILLEM-ALEXANDER POWER PLANT
Nuon’s showpiece power station in Buggenum, the Netherlands, features Shell Global Solutions clean coal technology (the Shell gasification process), HCN/COS hydrolysis and the Sulfinol process.

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PROJECTS IN DEVELOPMENT
Projects that feature Shell Global Solutions-licensed technologies currently undergoing detailed engineering include an integrated gasification combined-cycle plant in Korea, which is based on coal gasification, HCN/COS hydrolysis and the Sulfinol process, and a coal-to-urea application in Australia, which will use coal gasification, HCN/COS hydrolysis, ADIP-X and THIOPAQ O&G technologies.

THIOPAQ O&G
This process is highly suited to the removal of smaller quantities of sulphur (up to 150 t/d sulphur removal). THIOPAQ O&G technology, a joint co-operation between Shell International and Paques BV, integrates gas purification with sulphur recovery in a single unit. This bio-desulphurisation process uses naturally occurring bacteria that consume acid gases in an alkaline environment to convert the acid gases to bio-sulphur. The bio-sulphur has unique hydrophilic properties and is excellent for agricultural applications.

SulFerox®
This technology, a regenerable liquid redox process that achieves $\text{H}_2\text{S}$ abatement and sulphur recovery in a single unit, is highly suitable for the removal of 0.1–20 t/d of sulphur. The process forms solid sulphur particles that are filtered out.

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GS33791011 En(A)
SYNGAS (SYNTHESIS GAS) TREATING

Shell’s licensed treating technologies for the production of clean syngas

Shell Global Solutions

These can be licensed as standalone technologies; however, when supplied as an integrated solution with Shell gasification technology, additional value can be unlocked, as this helps to maximise heat recovery and the process’s energy efficiency.

HYDROLYSIS AND ACID-GAS REMOVAL TECHNOLOGIES

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Shell Global Solutions offers a wide selection of licensed technologies for syngas treating and sulphur removal to help meet product specifications (Figure 1).

Figure 1: An overview of Shell Global Solutions syngas treating technologies.
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ADIP®
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SULPHUR REMOVAL AND RECOVERY TECHNOLOGIES
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This thermal and catalytic process converts gaseous H₂S into elemental sulphur. A well-designed and operated Claus sulphur recovery plant can achieve overall conversion levels of at least 98%. The remaining gas separated from the last condenser, the tail gas, is either burned in an incinerator or further desulphurised in a tail-gas treatment unit.

SCOT®
The Shell Claus off-gas treating (SCOT) process has been developed to remove sulphur compounds from Claus tail gas to enhance sulphur recovery and comply with ever-increasingly stringent emission regulations. The tail-gas treating unit can be designed to meet World Bank emission standards and achieve sulphur recovery efficiency levels of 99.98% or higher.

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SYNGAS (SYNTHESIS GAS) TREATING
Shell’s licensed treating technologies for the production of clean syngas
Shell Global Solutions

Raw syngas often requires further processing for it to meet product specifications, as the concentrations of components such as carbon dioxide (CO₂), hydrogen sulphide (H₂S), carbonyl sulphide (COS), ammonia (NH₃) and hydrogen cyanide (HCN) are functions of the coal or residue feedstock.

Shell Global Solutions offers a wide selection of licensed technologies for syngas treating and sulphur removal to help meet product specifications (Figure 1).

These can be licensed as standalone technologies; however, when supplied as an integrated solution with Shell gasification technology, additional value can be unlocked, as this helps to maximise heat recovery and the process’s energy efficiency.

HYDROLYSIS AND ACID-GAS REMOVAL TECHNOLOGIES
Shell Global Solutions licenses the following technologies for hydrolysis and acid-gas removal.

HCN/COS hydrolysis
This removes HCN and COS. Catalytic conversion creates NH₃ and H₂S, which can be removed easily in downstream processes. The catalyst can be sourced through Shell’s catalyst company, CRI Catalyst Company. This process efficiently removes both HCN and COS.

Sulfinol®
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Figure 1: An overview of Shell Global Solutions syngas treating technologies.

AT A GLANCE

Customer driver: Delivering clean syngas
Solution: Shell Global Solutions licenses a wide range of technologies for hydrolysis and acid-gas removal, and sulphur removal and recovery
Value delivered: Cost-effective removal of contaminants from raw syngas
Proof point: More than 1,000 Shell Group operations and licensees
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PROOF POINTS

WILLEM-ALEXANDER POWER PLANT
Nuon’s showpiece power station in Buggenum, the Netherlands, features Shell Global Solutions clean coal technology (the Shell gasification process), HCN/COS hydrolysis and the Sulfinol process.

SANNAZZARO REFINERY
Eni’s refinery near Pavia, Italy, creates syngas from heavy residues, which it supplies to the nearby EniPower power plant. The plant features cutting-edge technologies, including Shell Global Solutions residue gasification and HCN/COS hydrolysis technologies.

PROJECTS IN DEVELOPMENT
Projects that feature Shell Global Solutions-licensed technologies currently undergoing detailed engineering include an integrated gasification combined-cycle plant in Korea, which is based on coal gasification, HCN/COS hydrolysis and the Sulfinol process, and a coal-to-urea application in Australia, which will use coal gasification, HCN/COS hydrolysis, ADIP-X and THIOPAQ O&G technologies.

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ADIP, SCOT, SulFerox and Sulfinol are Shell trademarks.
The spread between sweet and sour crude prices has led refiners to increase their use of high-sulphur crudes. This can improve refinery margins but generates greater quantities of sulphur and, consequently, increased emissions of SO2. Strict environmental regulations, both at the refinery and in refined product markets, put pressure on a refiner to limit SO2 emissions and to generate refined products that contain less organic sulphur.

Large amounts of high-sulphur residue can be economically converted to high-value products in new or modified units. Markets for smaller volumes of high-sulphur residue are more limited: they are typically used in bitumen markets or electrical power production. Meanwhile, many refiners are choosing to consume excess high-sulphur residue on-site to generate steam and electricity, which requires facilities to capture SO2 from the flue gas generated by the high-sulphur fuel.

When flue gas streams contain low concentrations of SO2, non-regenerable SO2 scrubbers are often used. These:

- consume commonly available alkaline materials such as lime, limestone and sodium hydroxide;
- generate waste products that are most often directed either to landfill or to waste-water treating systems; and
- cause less air pollution, but have greater impact on waste-water and landfill resources.

At higher SO2 concentrations or when more-stringent limitations for waste-water and landfill disposal apply, pressure on refiners to consider regenerable SO2 scrubbing systems increases. These systems direct the sulphur into existing by-product market streams and away from air, wastewater and landfill facilities.

The Cansolv® SO2 Scrubbing System controls emissions and captures additional by-product value from the SO2 emitted in various refinery flue gas streams, such as those generated by fluidised catalytic cracking units, process heaters and boilers, sulphur plants and spent acid regeneration units. The SO2 can be recycled to the sulphur recovery unit to produce marketable sulphur or it can be converted to sulphuric acid in a sulphuric acid unit and sold into acid markets.

ABOUT THE TECHNOLOGY
There is wide use of alkali-reagent-type processes that convert SO2 to calcium or sodium sulphate in the power and energy sectors to control SO2 emissions from combustion systems. These processes create aqueous and solid waste streams that must be disposed of to landfill or waste-water treating systems, if marketable byproduct markets cannot be found.

Crucially, the Cansolv SO2 scrubbing system is regenerable: a proprietary amine technology captures and releases a pure stream of SO2 that is converted to marketable by-products. It generates a small fraction of the waste generated by alternative non-regenerable, alkaline reagent processes, and consumes much less reagent than non-regenerable processes. High-cost consumable absorbents are not required, and effluents are reduced to a minimum.

This technology has enjoyed rapid take-up since its first commercial application in 2002: 15 units are operating.

The technology’s developer, gas emissions treating specialist Cansolv Technologies Inc., is wholly owned by Shell Global Solutions International BV.
start-up or in construction phase and more are in the detailed engineering or procurement phase.

**PROCESS DESCRIPTION**

This patented technology uses an aqueous amine solution to achieve highly efficient, selective absorption of SO$_2$ from flue gas. The key process steps are (Figure 1):

1. Feed gas is quenched and saturated in a circulated water pre-scrubber.
2. The gas contacts the lean amine solution in a counter-current absorption column.
3. SO$_2$ is absorbed and the treated gas exits the absorber to atmosphere.
4. SO$_2$-rich amine from the absorption column is pumped through a lean–rich amine heat exchanger for energy recovery and on to the regeneration column.
5. Steam stripping regenerates the lean amine solution, and the SO$_2$ is recovered as a pure, water-saturated product.
6. Lean amine is pumped from the stripper reboiler to the absorption column through the lean–rich amine heat exchanger and the lean amine cooler.
7. By-product SO$_2$ is directed to by-product management systems and is converted to various products, including liquid SO$_2$, sulphuric acid and elemental sulphur.

**PERFORMANCE DATA**

The technology is a highly flexible system and is adaptable to a wide variety of industrial applications, gas flow rates and SO$_2$ concentrations. Licensed units treating gas flow rates from 4,000 to 486,000 Nm$^3$/h and SO$_2$ concentrations from 800 to 12,000 vppm are operating successfully, and units are under construction to process up to 1,750,000 Nm$^3$/hr of flue gas.

SO$_2$ emissions below 20 ppmv can be achieved with base design configuration, and with minimal effluent production.

Moreover, the system has been designed for reliability: five years’ uninterrupted run time has been achieved on 40,000-Nm$^3$/h applications.

**BUSINESS VALUE**

The technology can help refiners to meet stringent emissions regulations by removing SO$_2$ from refinery gas streams and flue gases, and recycling SO$_2$ from sulphuric acid plant tail gases.

In certain applications, it can also help to enhance margins. For instance, in sulphur recovery unit applications, capacity can be increased by over 12%. Moreover, marketable by-products are recovered (high-quality SO$_2$, sulphur and sulphuric acid) and there is no solid waste.

As it is a regenerable system, the Cansolv SO$_2$ scrubbing system can help to ease many of the environmental and market-induced pressures that are associated with using of greater quantities of opportunistic crudes.

**PROOF POINTS**

Faced with stricter SO$_2$ regulations, a refinery in California, USA, needed to find an alternative solution to treat the tail gas of its alkylation spent acid regeneration plant, as the existing ammonium sulphate process was troublesome and did not integrate well with the refinery sulphur product chain.

A Cansolv SO$_2$ scrubbing system was selected to replace the existing ammonium sulphate system. Since the unit’s start-up in 2002, performance has exceeded the targeted design conditions. The refiner has decoupled the operation of the acid plant from its SO$_2$ emissions by exploiting the technology's ability to treat a range of inlet SO$_2$ concentrations. The Cansolv SO$_2$ scrubbing system has consistently met SO$_2$ emissions of 20 ppmv or less while treating acid plant tail gas with SO$_2$ content as high as 6,000 ppmv.

For further information, please visit our website at www.shell.com/globalsolutions
ABOUT THE TECHNOLOGY
For ultra-high levels of sulphur recovery, the CANSOLV TGT+ sour gas treating system can serve as a destination for all the plant’s sour gas streams, including:
- flash gases from the acid gas removal unit (AGRU);
- treated residue gas from the acid gas enrichment unit (AGEU);
- tail gas from the Claus sulphur recovery unit (SRU);
- sulphur degasser off-gas;
- sour water stripper off-gas; and
- disulphide oils generated in caustic treating of extracted natural gas liquids (NGL) or condensate.

In addition, the CANSOLV TGT+ system is highly adaptive to changes in process loads and the type and quantity of the compounds being treated.

The system combines the following technologies:
- the CANSOLV SO$_2$ scrubbing process; and
- the Shell Global Solutions Sulfinol® or ADIP® process.

AT A GLANCE
Customer driver: Growing development of highly sour natural gas resources; increasingly stringent emission regulations
Solution: The CANSOLV tail gas treating plus (TGT+) system for ultra-high sulphur recovery is based on Cansolv Technologies Inc.’s sulphur dioxide (SO$_2$) scrubbing process*
Value delivered: Cost-effective and simplified process line-up with centralised treating of all sulphur-containing process off-gases
Proof point: Since 2002, 19 CANSOLV licensed units have come online or are under construction

Natural gas reservoirs brought into production in recent years have contained increasing quantities of carbonyl sulphide, mercaptans and other organic sulphur species as well as hydrogen sulphide and carbon dioxide. More complex process line-ups are required to manage these contaminants. Tightening product specifications and stricter environmental emission standards have added additional levels of complexity.

The CANSOLV TGT+ system is an integrated sour gas treating solution that enables ultra-high overall sulphur recovery efficiency (up to 99.99% of the total sulphur present in the feed gas to the processing plant) from sour gas streams while minimising process line-up complexity and cost.

Figure 1: The CANSOLV TGT+ system. Tail gas from the Claus SRU and overhead off-gases from the AGRU flash gas absorber, AGEU and degasser are routed directly to the thermal incinerator, where the sulphur species are burned to SO$_2$. The incinerated gas is cleaned and cooled in a wash tower, and then enters the CANSOLV SO$_2$ absorber where SO$_2$ is preferentially removed.
The CANSOLV SO₂ scrubbing process is a post-combustion regenerable wet scrubbing process that uses a proprietary aqueous amine solvent to remove SO₂. The captured SO₂ is recycled as a pure stream to the SRU reaction furnace, where it reacts with incoming H₂S in the acid gas to form elemental sulphur.

SRU tail gas and other sulphur-containing gas streams are directed to a thermal oxidiser where all the sulphur compounds are converted to SO₂ (Figure 1). The incinerated gas is cleaned and cooled in a wash tower before entering the CANSOLV SO₂ absorber, where SO₂ is selectively removed.

The CANSOLV solvent is highly selective to SO₂. No other compounds in the gas are absorbed: they are discharged directly to atmosphere through the stack. The SO₂-containing solvent leaves the absorber and is regenerated using steam to produce a concentrated SO₂ stream that can be accommodated by the SRU.

BUSINESS VALUE
The CANSOLV TGT+ line-up helps to achieve the most stringent emission standards mandated in different jurisdictions, including those mandated by the World Bank (SO₂ stack emission <150 mg/Nm³), at competitive capital and operating costs while minimising process line-up complexity.

Compared with conventional process line-ups used to treat complex gases, CANSOLV TGT+ offers:

- an increase in the overall sulphur recovery efficiency to 99.99%;
- a decrease in complexity of the process line-up;
- an outlet for the disulphide oils; and
- competitive capital and operating costs.

HAVE YOU CONSIDERED HOW YOU CAN

- achieve 99.99% overall sulphur recovery efficiency in your sour gas processing facility?
- cut the cost of sulphur recovery?
- reduce the complexity of your sour gas treating facility while achieving higher recovery?

SRU TAIL GAS APPLICATION
A CANSOLV SO₂ scrubbing process has operated in a 30t/d SRU tail-gas application at a European chemical plant since 2002. It desulphurises the flue gas from a thermal oxidiser that receives feed streams, including Claus unit tail gas and a side stream of waste high-sulphur compounds, that accumulate in storage from operations. Recycling SO₂ to the SRU expands its sulphur-recovery efficiency by reducing the thermal stage combustion air requirement while controlling total sulphur emissions to less than 100 ppmv and as low as 20 ppmv.

The operation of the plant has been stable and reliable. In addition, solvent degradation has been lower than expected, which indicates a very low make-up requirement.

SPENT ACID REGENERATION APPLICATION
The CANSOLV SO₂ scrubbing process has treated tail gas from a 400-t/d spent acid unit at the sulphuric acid plant at a refinery in California, USA, since 2002. The recovered SO₂ is sent to the front end of the acid plant for conversion to sulphuric acid.

Normal operation has demonstrated a steady-state SO₂ concentration in the treated gas of between 10 and 20 ppmv. The process has been easy to adapt to changing conditions.
Gas development projects face growing challenges from increasingly sour resources, tighter sales specifications and stricter environmental emission standards. The Sulfinol-M sour-gas-treating process can be the only single-solvent solution available for meeting all specifications and sulphur dioxide (SO2) emission limits.

ABOUT THE TECHNOLOGY

Shell Global Solutions has a long history of developing gas-treating processes; its first Sulfinol unit, for example, started up in 1964. More than 220 Shell facilities and licensees have applied the technology, and it has established a track record of high levels of performance and reliability. The organisation continues to improve the technology, and in 1980 it introduced Sulfinol-M, which employs a second-generation solvent that can lead to process line-up simplification (Figure 1).

SOLVENT DESCRIPTION

The Sulfinol-M solvent employs a hybrid solution of a tertiary amine, methyl diethanolamine (MDEA), with Sulfolane and water.

A typical line-up for treating sour gas requires multiple process steps

Figure 1a: In a typical line-up for treating contaminated gas, multiple process steps are required for acid gas removal (left). H2S, CO2, and some COS are removed in the acid gas removal unit (AGRU); RSH and water are removed in the molecular sieve unit, and COS and other organic sulphur compounds are dealt with in additional units downstream.

A gas treating line-up employing Sulfinol-M technology is much simpler

Figure 1b: A gas treating line-up employing Sulfinol-M technology (right) is simpler: H2S, CO2, RSH, COS and organic sulphides are removed in the AGRU, and the molecular sieve unit is needed only for dehydration. In this case, there is no need for a regeneration gas absorber or a regenerator.
**PROOF POINT**

**EMMEN GAS PLANT, THE NETHERLANDS**

The 300-Mscf/d Emmen gas-desulphurisation plant processes sour gas from a variety of small gas fields in the north-east of the Netherlands. Sour gas is treated in two parallel trains using Sulfinol and molecular sieve units to remove H2S, RSH and water. Each of the two parallel Sulfinol trains has five Sulfinol-M absorbers sharing a common regenerator.

The plant was designed to cope with a wide range of sour gas compositions (0.1–1.0 vol% H2S, 2.0–5.0 vol% CO2 and up to 90 ppmv RSH) while meeting stringent product specifications (less than 3.5 ppmv H2S and less than 7 ppmv RSH). The feedstock is characterised by a high CO2/H2S ratio (up to 25 vol/vol). This imposes special requirements on the design and operation of the treating units in view of the need to provide a suitable feed to the Claus sulphur recovery unit (SRU): preferably more than 40 vol% H2S.

As a result, the plant has two key features:

- The high H2S/CO2 selectivity of Sulfinol-M is exploited in the main absorber and also in the enrichment step, where the H2S/CO2 ratio of the fat solvent is enhanced by selective flash regeneration. This enables the processing of sour gas with a high CO2/H2S ratio to produce a suitable Claus feed.
- It is highly integrated: five Sulfinol absorbers, including the SCOT absorber, share a common regenerator, which helps to reduce the plant’s capital cost.

**HIGH-PERFORMANCE GAS-TREATING SOLUTIONS SERIES**

**BUSINESS VALUE**

The application of Sulfinol-M technology offers many performance advantages compared with a conventional scheme for treating sour gas. Crucially, the treating line-up is simpler and it enables all-in-one removal of contaminants, which can help to reduce capital and operating expenditure.

Its other advantages include:

- reduced solvent degradation so no solvent reclamation is necessary;
- low solvent foaming tendency in the presence of heavy hydrocarbons; and
- high selectivity compared with traditional amines, which enables its use in Shell Claus off-gas-treating (SCOT™) applications and for acid gas enrichment.

In sour and syngas facilities, Sulfinol-M can often be the only single-solvent solution available for meeting all specifications and SO2 emission limits.

In addition, all the solvent chemicals can be sourced on the open market.

**HAVE YOU CONSIDERED HOW YOU CAN**

- Cost-effectively meet your facility’s environmental mandate?
- Minimise operator requirements?
- Reduce the use of expensive chemicals?
In today’s world, operators in the oil and gas industry are looking for solutions to reduce operating costs or debottleneck existing plants. Swapping to Shell Global Solutions ADIP-X or Sulfinol-X technology enables this with minimal or no capital expenditure.

ABOUT THE TECHNOLOGY
Shell Global Solutions has a long history of developing gas-treating processes; ADIP technology dates back to the 1950s, and Sulfinol technology to the 1960s. Since then, more than 750 Shell operating facilities and licensees have applied these technologies, which have established track records of high levels of performance and reliability.

Moreover, the organisation continues to improve the technology. In the early 2000s, it introduced the ADIP-X and Sulfinol-X technologies: enhanced versions that use accelerated reaction kinetics for better CO₂ and organic sulphur removal from gases. A typical process line-up is shown in Figure 1.

TECHNOLOGY DESCRIPTION
The ADIP-X and Sulfinol-X technologies are both water based, and use two amines: methyl diethanolamine (MDEA) as the main reactant and piperazine as the accelerator. Sulfinol-X uses an additional component, Sulfolane, to provide enhanced organic sulphur removal capabilities. ADIP-X and Sulfinol-X can both facilitate efficient and stable operations owing to their characteristics of low levels of:

- hydrocarbon solubility;
- foaming;
- fouling;
- corrosion; and
- degradation.

ADIP-X AND SULFINOL-X OFFER MANY ADVANTAGES COMPARED WITH ALTERNATIVE SOLVENTS USED IN ACID-GAS REMOVAL SERVICES: IN PARTICULAR, THEY HAVE HIGH CARRYING CAPACITY AND ARE NOT CORROSIVE.
HIGH-PERFORMANCE GAS-PROCESSING SOLUTIONS SERIES

BUSINESS VALUE

ADIP-X and Sulfinol-X offer many advantages compared with alternative solvents used in acid-gas removal services: in particular, they have high carrying capacity and are not corrosive. These features can help operators to reduce operating expenditure or increase plant capacity with little or no additional investment.

By switching to ADIP-X or Sulfinol-X, operators can also benefit from:

■ enhanced treating performance;
■ reduced steam requirements owing to their lower solvent circulation rates and heats of reaction; and
■ increased reliability owing to low levels of foaming, fouling, degradation and corrosion.

In addition, because ADIP-X and Sulfinol-X solvents have very low solvent degradation rates and do not form by-products, solvent reclamation is not required. Implementation is straightforward, as minimal or no hardware modifications are required and all the solvent chemicals can be sourced on the open market.

PROOF POINTS

SHELL REFINERY

A Sulfinol-D gas-treating plant designed in 1966 for a Shell refinery in the USA removed CO₂ from 75 MMscf/d of hydrogen upstream of a methanator.

To lower the solvent circulation rate and eliminate the reclamation of diisopropanolamine (DIPA)–oxazolidone, the amine used in the solvent was switched from DIPA to an MDEA–piperazine mixture between 2008 and 2010. As the heat transfer to the reboiler is constrained by limited regenerator overhead cooling, sulfolane is used to manage the lean loading of the solvent at low heat input.

The solvent swap, first to aqueous MDEA/piperazine and then to Sulfinol-X, therefore offers improved deep removal of CO₂, (lower solvent circulation) and improved waste management (no oxazolidone formation). The feed gas to the absorber has about 17 mol% CO₂ whereas the treated gas typically has <50 ppmv CO₂ since the change to Sulfinol-X was made.

OMAN LNG

Oman LNG was suffering solvent deterioration in its LNG trains that was affecting unit capacity. After a thorough investigation, it was decided that a solvent swap to ADIP-X technology was the optimal solution.

The solvent in each of its three trains was swapped in turn between 2006 and 2008.

Because ADIP-X does not form degradation products, the solvent swap has enabled the operating capacity to be restored and maintained. In addition, the new solvent has reduced the C6+ losses to the fuel gas system via the off-gas. As a result, more C6+ hydrocarbons are being recovered, which has enabled Oman LNG to increase condensate production by 2.5 t/d. This increased condensate production provides significant value. In addition, not having to reclaim solvent off-site has further reduced the company’s operational costs.

HAVE YOU CONSIDERED HOW YOU CAN

■ Increase your facility’s CO₂ or organic sulphur removal capacity?
■ Reduce your operating costs?
■ Eliminate solvent reclamation?

ADIP and Sulfinol are Shell trademarks.

For further information, please visit our website at www.shell.com/gasprocessing or email us at gasprocessing@shell.com.

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GS33850312 En(A)
In today’s world, operators in the oil and gas industry are looking for solutions to reduce operating costs or debottleneck existing plants. Swapping to Shell Global Solutions ADIP-X or Sulfinol-X technology enables this with minimal or no capital expenditure.

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Shell Global Solutions has a long history of developing gas-treating processes; ADIP technology dates back to the 1950s, and Sulfinol technology to the 1960s. Since then, more than 750 Shell operating facilities and licensees have applied these technologies, which have established track records of high levels of performance and reliability.

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HAVE YOU CONSIDERED HOW YOU CAN

- Increase your facility’s CO₂ or organic sulphur removal capacity?
- Reduce your operating costs?
- Eliminate solvent reclamation?
Refineries and gas plants worldwide have reported lower operating costs, extended cycle lengths and reduced pressure drops as a result of installing Criterion’s state-of-the-art catalysts in their Claus tail-gas treating units.

Well-operated Claus tail-gas units are increasingly important as operators strive to meet their sulphur emissions mandates. Although these processes can provide greater than 99.9% sulphur recovery, careful selection of the catalyst is necessary to ensure optimum performance and process economics.

**CATALYST SELECTION**

When selecting a Claus tail-gas catalyst, there are three key aspects to consider.

**Cost:** Criterion’s low bulk density C-234 catalyst offers the optimal balance between cost and activity

**Pressure drop:** Criterion’s C-534 and C-734 catalysts offer low start-of-run (SOR) pressure drop performance, unsurpassed in the industry (see Figure 1), which maximises the cycle time between catalyst replacements.

**Activity:** Criterion’s C-734 catalyst offers top-tier activity for lower temperature conversion of sulphur dioxide (SO₂), carbonyl sulphide (COS) and carbon disulphide (CS₂) to hydrogen sulphide (H₂S).

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**Figure 1: Tail-gas catalysts’ annual pressure drop.** Pressure drop is a key parameter for Claus tail-gas treating catalysts: the lower the pressure drop, the less the chance there is of operational upsets. The larger particle size of Criterion’s C-234, C-534 and C-734 catalysts means they outperform the competition in this crucial aspect.

---

Criterion offers a range of tail-gas treating catalysts and works with customers to select the most appropriate candidate for each individual unit. We also help customers to optimise treatment processes in terms of the hardware involved and the conditions in the unit.
ABOUT THE CATALYSTS

C-234, a low-bulk-density trilobe catalyst, has found wide acceptance globally: over 2,270 t of this catalyst has been installed worldwide.

The catalyst is outstanding in low-temperature service: it operates at reactor inlet temperatures from 225°C. Substantial fuel savings can therefore be realised.

Owing to its high surface area, low pressure drop and excellent catalytic activity, C-234 is also highly suitable for operations where there are problems with carbon or soot formation, or when cycle length is curtailed.

C-234 also performs well in units that operate at conventional reactor inlet temperatures (280°C or higher). So, when a low fill cost is paramount, C-234 is the most appropriate Criterion Claus tail-gas treating catalyst to use.

THE VALUE OF LOW-TEMPERATURE OPERATION

Employing a high-activity catalyst enables operators to cut reactor inlet temperatures from 280 to 240°C or lower, thereby reducing the amount of natural gas required by the process. Criterion’s low-temperature catalysts, C-234 and C-734, have sufficient activity to convert the same level of non-H₂S sulphur to H₂S as a conventional catalyst such as C-534 but at a lower temperature. Running at a lower operating temperature can also help to prolong cycle life.

One European client calculated that it would save $4,800 a year for every cubic metre of C-234 that it installed. The entire cost of the catalyst was paid back in less than two years by operating at the lower temperature.

C-534

C-534 is a high-strength spherical catalyst that offers improved pressure drop characteristics.

It has established an enviable track record in the industry and achieved cycle lengths of over 10 years in Shell Claus off-gas treating (SCOT®) units. Its physical strength and thermal stability safeguard it from the typical upsets encountered in tail-gas treating.

C-734

Extensive research and development led to the creation of C-734, Criterion’s newest and highest-activity Claus tail-gas catalyst. Not only does this spherical catalyst offer among the lowest pressure drop performance in the industry, it also provides top-tier catalytic activity.

The high activity is the result of an all-new substrate that Criterion has developed. The improved site architecture of the new substrate provides better metal dispersion and support interaction. Criterion’s C-734 superior activity allows very low reactor inlet temperature operation, from 215°C.

In addition, C-734 features excellent COS and CS₂ conversion activity, and, in many cases, obviates the need for expensive COS/CS₂ hydrolysis catalyst in the Claus reactors.

C-734 also performs well in units that operate at conventional reactor inlet temperatures.

CATALYTIC INCINERATION – C-099

Refineries are increasingly cutting their energy bills and reducing emissions of greenhouse gases and harmful pollutants such as sulphur trioxide (SO₃) by replacing their thermal incinerators with a catalytic variant that is charged with Criterion’s C-099 catalyst.

These incinerators are the final step in the sulphur complex and are designed to convert the remaining traces of sulphur compounds, including H₂S, COS and CS₂, to less harmful SO₂ before they enter the atmosphere.

Thermal incinerators are normally operated at about 700°C and can produce SO₃. Catalytic incineration provides an energy-saving alternative, as it operates at about 300°C. The use of Criterion C-099 catalyst behind a tail-gas unit can offer savings of 60% in the fuel that would be required for a similar thermal incinerator. In addition, C-099 has extremely low selectivity for SO₃. C-099 has operated well for over 10 years in several locations.

CRITERION’S C-234, C-534 AND C-734 CLAUS TAIL-GAS TREATING CATALYSTS ACCOUNT FOR 80% OF THE WORLD’S INSTALLED CAPACITY. THEY ARE INSTALLED IN OVER 270 REACTORS WORLDWIDE, INCLUDING THE MAJORITY OF THE INDUSTRY’S LARGEST UNITS.
SELECTING THE OPTIMUM CLAUS TAIL-GAS CATALYST

CRITERION’S TAIL-GAS TREATING CATALYSTS:

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>C-234</th>
<th>C-534</th>
<th>C-734</th>
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</table>

²Weight percent retained on 20-mesh screen after tumbling 1 h at 40 rpm.

1An 8.0-mm sphere is also available for grading purposes.

PROOF POINT: CHINA PETROLEUM AND CHEMICAL CORPORATION (SINOPEC)

Sinopec’s Zhongyuan Puguang natural gas purification plant in Sichuan Province, China, features Claus conversion processes and tail-gas treating units that include C-234 catalyst.

Operating results confirm that the catalyst has:
- very high stability. The reactor inlet temperature and the temperature differential distribution after six months were almost the same as the SOR results.
- extremely fast and complete SO₂ hydrogenation performance
- excellent activity. The COS at reactor outlet is 0–20 ppm, and the carbon monoxide content at the reactor outlet is close to zero.

In addition, operating the tail-gas treating units at low temperatures significantly reduces energy consumption.

PROOF POINT: NEW ZEALAND REFINING COMPANY

New Zealand Refining Company’s Whangarei refinery cut its reactor inlet temperature from 280 to 235°C, which resulted in a 20–22% reduction in fuel gas use after switching to C-734 catalyst in its SCOT unit. It selected C-734 because of its high catalytic activity and low pressure drop characteristics. The unit has shown stable operation since it started up smoothly in May 2010.
CONTACT US

For more information about how we can help you to enhance operational performance, meet increasingly stringent environmental regulations and increase revenues, visit us at www.criterioncatalysts.com.

*SCOT is a Shell trademark

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