



## Technology Portfolio

For more information, please contact Hofung Technology, or send an email to [sales@hofung-technology.com](mailto:sales@hofung-technology.com).

**TABLE OF CONTENTS**

**1.0 TECHNOLOGY LEAFLETS & PICTURES**

**2.0 BOX SCORE SULFUR RECOVERY PROJECTS**

## **1.0 TECHNOLOGY LEAFLETS & PICTURES**

## Build Sulfur Plants & Detailed Pictures



Project: ISLA, Curacao  
Client: PDVSA  
Capacity: 100 T/day

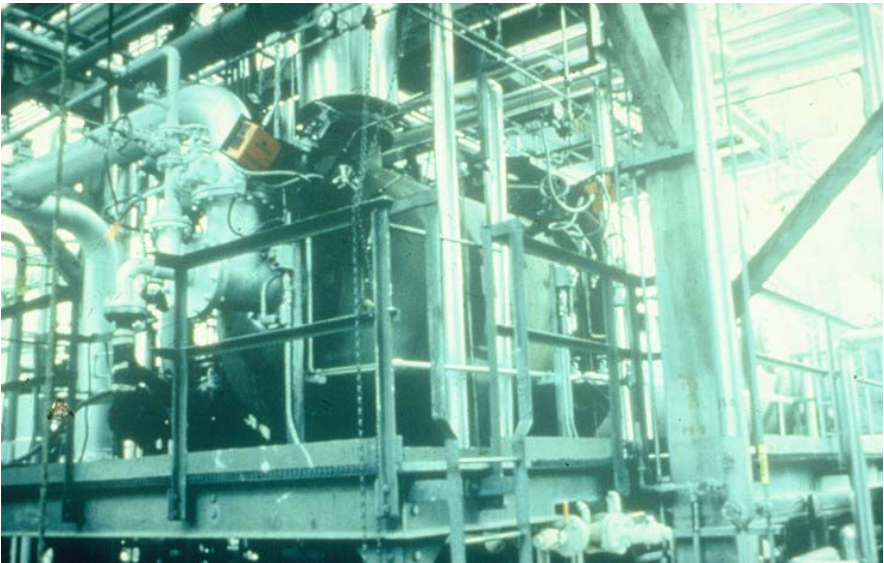
## Build Sulfur Plants & Detailed Pictures



Project: Sulfur Degasification Vessel (1986)  
Client: BEB  
Capacity: 2 X 900 T/day



# Build Sulfur Plants & Detailed Pictures



Main Combustion Chamber  
Project: 02 Enrichment (1985)  
Client: Conoco, Lake Charles

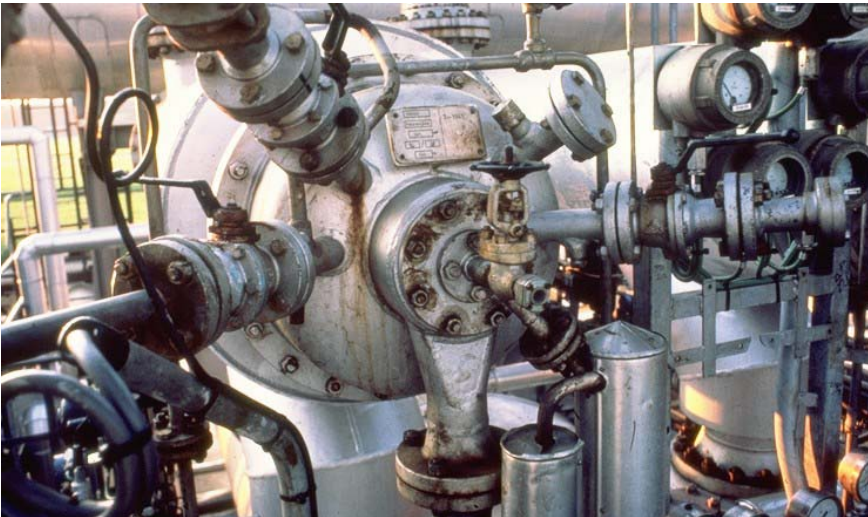


Project: Deep Cooler  
Client: Wintershall, Rutenbrock



Project: Reactor + Condensers + Waste Heat Boiler (1985)  
Client: BP Lavera, France

# Build Sulfur Plants & Detailed Pictures



Line Burner



Line Burner + Reactor



Air Preheater + Main Combustion Chamber



Coalescer

# Build Sulfur Plants & Detailed Pictures



SUPERCLAUS Catalyst



Burnt Timber Gas Plant



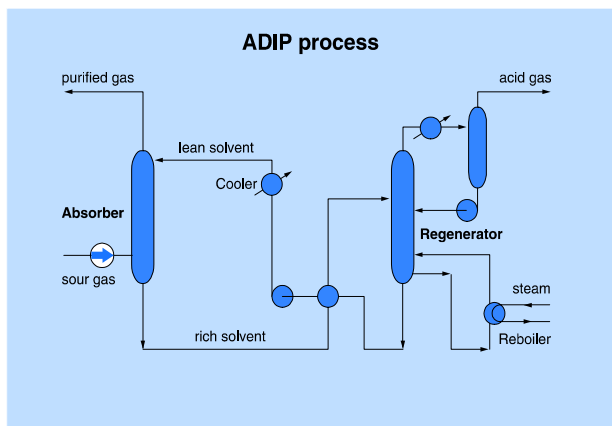
Radiation Wall MCC



Main Burner

# GAS TREATING (REFINERY / NATURAL GAS)

## ADIP PROCESS



### APPLICATIONS

The ADIP process is a regenerative process developed to reduce H<sub>2</sub>S in gas to very low concentrations, while a good selectivity for H<sub>2</sub>S in the presence of CO<sub>2</sub> can be achieved. The ADIP process covers the use of the aqueous solution of di-isopropanol amine (DIPA) and the aqueous solution of methyldiethanol amine (MDEA). MDEA is used for those applications in which high selectivity for H<sub>2</sub>S is required. Depending on operating conditions 20 - 60% of the CO<sub>2</sub> is co-absorbed if DIPA is used as the ADIP solvent, while this can be reduced to 10 - 30% if MDEA is applied as the solvent. The ADIP process can also be used for enrichment of acid gas feed to a sulfur recovery plant, to achieve a higher H<sub>2</sub>S content. Integration of gas treating with the SCOT solvent system is an option.

### DESCRIPTION

The H<sub>2</sub>S containing gas is contacted counter-currently in an absorption column with ADIP solvent. The regenerated solvent is introduced at the top of the absorber. The H<sub>2</sub>S loaded solvent (rich solvent) from the absorber is heated by heat exchange with regenerated solvent and is fed back to the regenerator, where it is further heated and freed of the acid gases with steam.

The acid gases removed from the solvent in the regenerator are cooled with air or water, so that the major part of the water vapor is condensed. The sour condensate is reintroduced into the system as a reflux.

The acid gas is passed to the sulfur recovery plant (Claus plant) in which elemental sulfur is recovered from the H<sub>2</sub>S.

### OPERATING CONDITIONS

Absorber operating pressure can be up to 150 bar. Gas temperature can vary from ambient up to 60°C.

### UTILITIES

The estimated consumption varies widely with feed composition and product specification. LP steam consumption amounts to 0.4 to 2.8 ton/ton acid gas removed.

### FEATURES

- ☆ Reduction of H<sub>2</sub>S to very low concentrations.
- ☆ Low steam consumption and solvent circulation.
- ☆ Carbon steel equipment.
- ☆ Resistant against degradation (DIPA).
- ☆ No reclaimer required.
- ☆ Good selectivity for H<sub>2</sub>S in the presence of CO<sub>2</sub>.
- ☆ Reduced investment and operating costs with selective designs.

### REFERENCES

More than 450 ADIP units ranging in capacity from 1.900 Nm<sup>3</sup>/d to 12.200.000 Nm<sup>3</sup>/d and 19 t/sd to 7700 t/sd liquid hydrocarbons are in operation throughout the world, demonstrating the reliability of the process

### LICENSOR

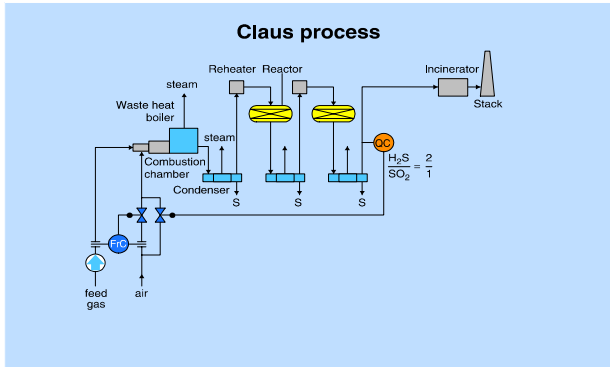
Jacobs Nederland B.V., Leiden, The Netherlands, is one of the three authorized licensors on behalf of Shell Research Ltd. since 1981.

Streams to be treated	Contaminants removed
Refinery gases: e.g. from HDS and cracking units	H <sub>2</sub> S
Natural gases	H <sub>2</sub> S, CO <sub>2</sub> (partly)
Reduced Claus tail gas (SCOT process)	H <sub>2</sub> S, CO <sub>2</sub> (partly)
Gas from oil or coal gasification in combined-cycle power stations	H <sub>2</sub> S, CO <sub>2</sub> (partly)
Claus feed gas enrichment	H <sub>2</sub> S, CO <sub>2</sub> (partly)



# SULFUR RECOVERY

## CLAUS PROCESS



### APPLICATIONS

The Claus process has been developed to recover elemental sulfur from H<sub>2</sub>S containing gases originating from gas treating plants such as alkanolamine units or physical solvent plants. Modern Claus plants should be able to process H<sub>2</sub>S/NH<sub>3</sub> containing gases as well, originating from Sour Water Strippers.

### DESCRIPTION

The Claus process is based on the combustion of part of the H<sub>2</sub>S to SO<sub>2</sub> and the subsequent reaction between the remaining H<sub>2</sub>S and the SO<sub>2</sub> produced, forming sulfur. There are two main varieties of the Claus process: straight through and split flow. The straight through process is used for feed gas containing more than 50% H<sub>2</sub>S while split flow is applied for gases containing 50 to 15% H<sub>2</sub>S. The sulfur recovery process consists of a thermal stage (combustion chamber, waste heat boiler) and two or three catalytic reaction stages (reheater, reactor and condenser). In the thermal stage, the Claus reaction takes place at a high temperature level (950-1350°C). The sulfur produced in this stage is condensed either in the waste heat boiler or in the condenser. Subsequently, the gas is reheated to a temperature of 200-300°C before introduction into each reactor stage. The heat generated from the reactions is used for steam production. In the thermal stage, a choice can be made between the production of LP, MP or HP steam. In the sulfur condensers LP steam is generated. The tail gas is sent to an incinerator or tail gas treater.

### OPERATING CONDITIONS

NH<sub>3</sub> in the total Claus feed gas can be processed up to 30 vol.%. Some feed gases may contain small amounts of heavy hydrocarbons and aromatics, operating experience up to 2 vol.%. Claus plants can

be designed for turndown ratios of 100-15%. Product sulfur has a purity of more than 99.9% -bright yellow- ; and contains less than 10 ppmwt H<sub>2</sub>S after degassing. H<sub>2</sub>S (stack) emission: 5-10 ppm vol. with thermal incinerator depending on the incinerator temperature and 10 ppm vol. with a catalytic incinerator.

### UTILITIES

Basis: 100 t/d sulfur recovery unit, 93 vol.% H<sub>2</sub>S in feed gas and catalytic incineration.

		Consumption	Production
LP steam	t/h	--	3.3
MP steam	t/h	--	10.2
Electricity	kW	220	--
Fuel gas	t/h	0.12	--
Boiler feed water	t/h	13.5	--
LP steam (plant heating)	t/h	0.4	--

### FEATURES

- ☆ Sulfur recovery with
  - two reactors : up to 96%
  - three reactors : up to 98%
  - (incl. a SUPERCLAUS® reactor stage: up to 99.4%)
- ☆ NH<sub>3</sub> destruction.
- ☆ Capability to burn heavy hydrocarbons and aromatics.
- ☆ Integrated sulfur degasification process.
- ☆ Energy saving through heat integration and waste heat recovery.
- ☆ High turndown.
- ☆ High reliability - less than 1% unscheduled shutdown time.
- ☆ Explosion proof equipment.
- ☆ Good accessibility to all equipment.
- ☆ Jacobs has facilities to manufacture, construct and assemble packaged units. Skid mounted and module mounted units have been supplied ranging from 3 to 70 t/d.

### REFERENCES

Since 1957 more than 225 Claus plants have been built throughout the world, ranging in capacity from 3 t/d up to 700 t/d. Sulfur recovery and gas sweetening projects are handled by a specialized project group with many years of experience. Feed back of operating experience and results of plant tests are utilized for continuous optimization of Jacobs' sulfur recovery process. Operating companies have shown their appreciation for Jacobs' technical after sales services and customer seminars.

### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands.

# SULFUR HANDLING

## SHELL SULFUR DEGASIFICATION PROCESS

The Shell Sulfur Degasification Process

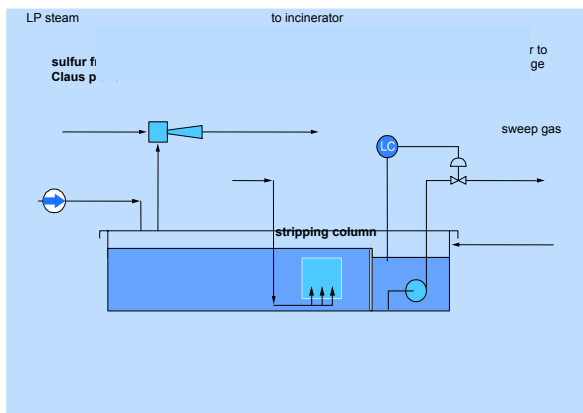


Figure 1

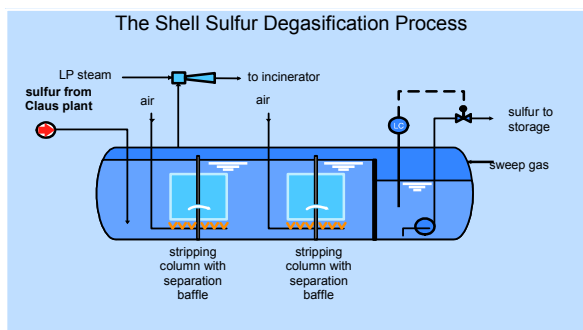


Figure 2

### APPLICATIONS

The Shell Sulfur Degasification Process has been developed to remove  $H_2S$  and  $H_2S_x$  from liquid sulfur eliminating potential toxic and explosion hazards associated with handling, transport and storage of liquid sulfur. Elemental, sulfur produced by the Claus process contains both physically dissolved  $H_2S$  and chemically bound  $H_2S$  in the form of hydrogen polysulfides (sulfanes):  $H_2S_x$ . Liquid sulfur produced typically contains 250-350 ppm wt  $H_2S$  mainly in the polysulfide form. The principle of sulfur degasification is to accelerate decomposition of the polysulfides according to  $H_2S_x \leftrightarrow H_2S + S_{x-1}$  and to remove the dissolved  $H_2S$  from the liquid sulfur. In the Shell Sulfur Degasification Process, the sulfur is degassed to less than 10 ppm wt  $H_2S/H_2S_x$ .

### DESCRIPTION

Degasification is carried out as a continuous process in the degasification compartment of the Claus plant sulfur pit or in a dedicated vessel. The actual degasification takes place in the stripping column where sulfur is vigorously agitated by bubbling air

through the liquid sulfur. As the stripping column is open at the bottom and the top, the sulfur can circulate through the stripping column and a thorough mixing with the total content of the degasification compartment is achieved. The original basic concept of one stripping column (figure 1) has been replaced by two columns with separation baffles (figure 2). The new concept allows for a large number of design variants. Tests proved that the residence time can be reduced to one third which permits the use of a smaller sulfur degassing vessel or sulfur pit. The essential simplicity of the process has been maintained: "it does not use a catalyst and has no moving parts".

### OPERATING CONDITIONS

In the Shell Sulfur Degasification Process, air stripping is applied without addition of chemicals. Air is supplied to the stripping column at a pressure of approx. 1.5 bara either as a slipstream from the Claus air blower or by a dedicated blower. Vent gas is charged to an incinerator or can be recycled back to the sulfur plant. The degassed sulfur flows over a weir to the pumping compartment and is pumped on level control to storage. The Shell Sulfur Degasification Process is an intrinsically safe system as the formation of an explosive  $H_2S$ /air mixture is prevented.

### UTILITIES

Utility consumption for the degasification of 100 t/d sulfur.

Electricity for compression of stripping air	: 5 kW
LP steam for ejector and air preheater	: 200 kg/h
Chemicals	: not required

### FEATURES

- ☆ Safer working conditions for handling liquid sulfur.
- ☆ Less corrosion in transport and storage equipment.
- ☆ Reduction of emission problems in the surrounding of the sulfur pit.
- ☆ No chemicals present in the gasified product sulfur.
- ☆ No moving parts.

### REFERENCES

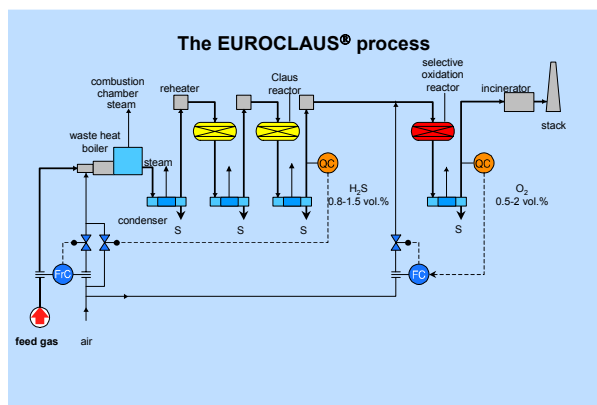
More than 150 Shell Sulfur Degasification systems ranging in capacity from 10 to 4000 t/d sulfur production are in operation or are under design/construction throughout the world demonstrating the reliability, simplicity and flexibility of the process.

### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands, is the exclusive worldwide licensor of behalf of Shell Research Ltd. since 1981.

# SULFUR RECOVERY

## EUROCLAUS PROCESS



### APPLICATIONS

The EUROCLAUS® process has been developed to recover elemental sulfur from H<sub>2</sub>S containing gases originating from gas treating plants such as alkanolamine units or physical solvent plants. The EUROCLAUS® process is an improvement of the SUPERCLAUS® process. Yields up to 99.7% overall sulfur recovery without any further tail gas clean up are possible.

### DESCRIPTION

The EUROCLAUS® process consists of a thermal stage followed by three catalytic reaction stages with sulfur removed between stages by condensers. Two reactors are filled with standard Claus catalyst while the last reactor is filled with the selective oxidation catalyst. In the thermal stage, the acid gas is burned with a substoichiometric amount of controlled combustion air such that the tail gas leaving the second reactor contains typically 0.8 to 1.0 vol.% of H<sub>2</sub>S and 100-200 ppmv SO<sub>2</sub>. This low SO<sub>2</sub> content is obtained with a hydrogenation catalyst which converts SO<sub>2</sub> to H<sub>2</sub>S in the bottom of the second reactor. The catalyst in the last reactor oxidizes the H<sub>2</sub>S to sulfur at an efficiency of more than 85%. However, because this catalyst neither oxidizes H<sub>2</sub>S to SO<sub>2</sub> nor reverses the reaction of sulfur and water to H<sub>2</sub>S and SO<sub>2</sub>, a total sulfur recovery efficiency up to 99.3% can be obtained. If a sulfur recovery efficiency of more than 99.3% is required, one additional Claus reactor stage may be installed upstream of the selective oxidation reactor.

### OPERATING CONDITIONS

Three main principles are applied in operating the EUROCLAUS® process:

- ☆ Operating the Claus plant with excess H<sub>2</sub>S to suppress the SO<sub>2</sub> content in the Claus tail gas.

- ☆ Selective reduction of SO<sub>2</sub> in the Claus process gas by means of a catalyst with hydrogenating properties.
- ☆ Selective oxidation of the remaining H<sub>2</sub>S in the Claus tail gas by means of special catalyst which efficiently converts the remaining H<sub>2</sub>S in the presence of water vapor and excess oxygen to elemental sulfur only.
- ☆ Other operating features, which apply for Jacobs' Claus process, are applicable for the EUROCLAUS® process as well, such as NH<sub>3</sub> destruction up to 30 vol.%, the capability to process small amounts of heavy hydrocarbons and aromatics up to 2 vol.%, turndown ratios of 100-15%. Producing 99.9% pure bright yellow sulfur.

### UTILITIES

Basis: 100 t/d sulfur recovery unit, 93 vol.% H<sub>2</sub>S feed gas and catalytic incineration.

		Consumption	Production
LP steam	t/h	--	3.3
MP steam	t/h	--	10.2
Electricity	kW	220	--
Fuel gas	t/h	0.12	--
Boiler feed water	t/h	13.5	--
LP steam (plant heating)	t/h	0.4	--

### FEATURES

- ☆ Application in both new and existing plants.
- ☆ The SUPERCLAUS® catalyst as applied in the SUPERCLAUS® process.
- ☆ Improved process controls of the SUPERCLAUS® stage.
- ☆ A final Claus reactor also containing hydrogenation catalyst.
- ☆ Long catalyst lifetime up to 10 years.
- ☆ Sulfur recovery up to 99.7%.
- ☆ Reduction of current SO<sub>2</sub> emissions up to 90%.
- ☆ Simple continuous operation.
- ☆ Low additional investment costs.
- ☆ NH<sub>3</sub> destruction.
- ☆ Capability to combust heavy hydrocarbon and aromatics.
- ☆ High turndown.
- ☆ High reliability - less than 1% unscheduled shutdown time.

### REFERENCES

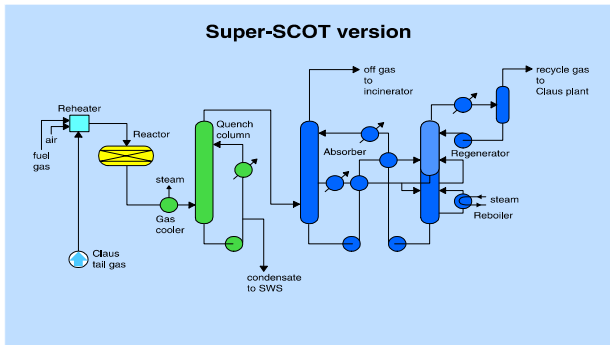
Since the first commercial demonstration of the EUROCLAUS® process in 2000, more than 12 plants are in operation or under construction in the first quarter of 2003.

### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands.

# CLAUS TAIL GAS TREATING

## LS-SCOT AND SUPER-SCOT PROCESS



### APPLICATIONS

The Shell Claus Off-gas Treating (SCOT) process has been developed to remove sulfur compounds from Claus tail gas to comply with air emission regulations. More recent developments to meet higher sulfur removal efficiencies are the Low Sulfur-SCOT and the Super-SCOT version.

The LS-SCOT uses a small concentration of an inexpensive additive to the amine.

The Super-SCOT applies two-stage regeneration in combination with a lower solvent concentration.

### DESCRIPTION

#### Low Sulfur-SCOT

The additive improves the regeneration of the solvent producing a better solvent leanness and thereby a lower off-gas H<sub>2</sub>S specification. Treated off-gas specifications as low as 10 ppmv H<sub>2</sub>S or 50 ppmv total sulfur (including COS/CS<sub>2</sub>) can be met. Because of the additive LS-SCOT units have to be designed preferably as stand-alone SCOT unit. The LS-SCOT version has however also successfully tested on integrated SCOT units with DIPA and MDEA.

#### Super-SCOT

The Super-SCOT version has been developed to achieve an H<sub>2</sub>S concentration of 10 ppmv H<sub>2</sub>S or a total sulfur content of less than 50 ppmv.

The principle of the Super-SCOT version is based on two stage stripping, optionally in combination with a lower lean solvent temperature.

The two features of improving stripping by two-stage regeneration and improving absorption by a lower solvent temperature can be applied separately or in combination.

In order to reach a specific leanness of the solvent (mol H<sub>2</sub>S/mol. amine) a specific steam rate (kg steam/m<sup>3</sup> solvent) is required.

A leaner solvent will result in a lower H<sub>2</sub>S concentration in the SCOT off-gas. However, for the purpose of lowering the H<sub>2</sub>S concentration in the SCOT-off gas, it is not necessary to regenerate the entire solvent flow to this lower leanness level.

It is well known that the solubility of H<sub>2</sub>S in amine solvents is increased when the temperature is lowered. A lower amine temperature results in a lower H<sub>2</sub>S partial pressure of the solvent, which enables the achievement of a lower H<sub>2</sub>S concentration in the SCOT off-gas.

### OPERATING CONDITIONS

Operating test data of LS-SCOT at three different locations

		Test 1	Test 2	Test 3
H <sub>2</sub> S in feed gas to absorber	vol. %	2.4	2.1	1.4
CO <sub>2</sub> in feed gas to absorber	vol. %	7.1	4.0	3.0
Total S in treated gas	ppmv	<50	<50	<50
Solvent temperature	°C	35	39	32
Solvent type		DIPA	MDEA	DIPA
Regenerable free base	wt. %	41	52	44
Actual total base	wt. %	42	53	48
Specific steam rate	kg/m <sup>3</sup>	120	135	132
Number of absorber trays		11	11	9

Operating data for the Super-SCOT unit at a refinery

		Test run no. 1	Test run no. 2
H <sub>2</sub> S in feed gas	vol. %	1.3	1.7
CO <sub>2</sub> in feed gas,	vol. %	3.0	2.5
Total S in treated gas	ppmv	<50	<50
Lean solvent temperature	°C	45	44
Steam rate specific (based on super-lean solvent quality only)	kg/m <sup>3</sup>	320	350
Regenerable free base solvent	wt. %	24	26
Actual total base solvent	wt. %	24.5	27

### REFERENCES

Since 1991 six LS-SCOT and six Super-SCOT units are in operation behind the Claus unit with a capacity between 30 t/d and 950 t/d. Three of the six Super-SCOT units have been designed to lower the steam consumption.

### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands, is one of the three authorized licensors on behalf of Shell Research Ltd. since 1981.

# CLAUS TAIL GAS TREATING

## SCOT PROCESS

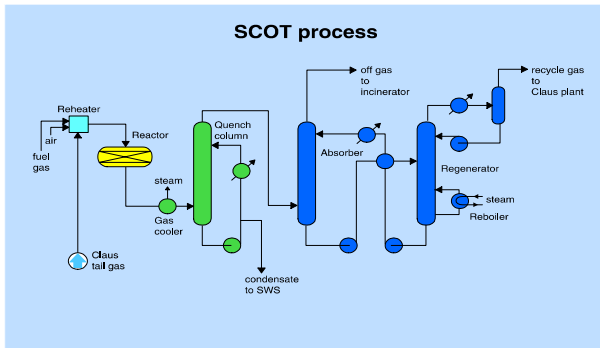


Figure 1

### APPLICATIONS

The Shell Claus Off-gas Treating (SCOT) process has been developed to remove sulfur compounds from Claus tail gas to comply with air stringent emission regulations. The standard SCOT process is able to easily meet less than 250 ppmv total sulfur in the SCOT off-gas, which corresponds to an overall sulfur recovery efficiency of 99.9% on intake.

### DESCRIPTION

The SCOT process essentially consists of a reduction section and an ADIP absorption section of special design. In the reduction section all the sulfur compounds (other than H<sub>2</sub>S) present in the non-incinerated Claus tail gas (SO<sub>2</sub>, COS, CS<sub>2</sub> and elemental S) are completely converted into H<sub>2</sub>S over a cobalt/molybdenum catalyst at 300°C in the presence of H<sub>2</sub> or a mixture of H<sub>2</sub> and CO.

The Claus tail gas feed to the SCOT process is heated to 300°C with an inline burner or heat exchanger with optionally added H<sub>2</sub> or a mix of H<sub>2</sub>/CO. If reducing gas, H<sub>2</sub> or CO, is unavailable, an inline burner is operated substoichiometrically to produce reducing gas. The heated gases then flow through a catalyst bed where sulfur compounds, including CS<sub>2</sub> and COS, are reduced to H<sub>2</sub>S. Process steam is generated in by cooling the gas to about 165°C in a heat recovery boiler and subsequently by direct contact cooling with water to 40°C. Water vapor in the process gas is condensed and the condensate is sent to a sour water stripper. The cooled gas, which normally contains up to 3% vol. H<sub>2</sub>S and up to 20% vol. CO<sub>2</sub> or more is countercurrently washed with an alkanolamine solvent in an absorption column designed to absorb almost all H<sub>2</sub>S but relatively little CO<sub>2</sub>. The treated gas from the absorption column contains only traces of H<sub>2</sub>S and is burned in a standard Claus incinerator. The concentrated H<sub>2</sub>S is recovered from the rich solvent in a conventional stripper and is recycled to the Claus unit. The SCOT units are designed for minimum pressure drop so that they can be added easily to existing Claus units.

If insufficient pressure is available, a gas booster can be installed, preferably between the cooling tower and the absorption tower.

### INTEGRATION

Integration with the amine treater upstream the Claus plant can lead to considerable equipment savings. The Add-on SCOT in figure 1 has a complete independent solvent system.

### The common regenerator SCOT

The rich amine from the SCOT absorber is routed to the regenerator of the amine system upstream of the Claus unit and therefore requires one common solvent. A requirement for this line-up is that the existing regenerator has adequate capacity to cope with the additional solvent from the SCOT absorber.

### The cascaded SCOT

Since the acid-gas partial pressure in the SCOT absorber is low, the "rich" solvent from the SCOT is in fact only partially loaded. This solvent can therefore be routed to an intermediate tray of another absorber where its remaining acid-gas loading capacity can be used.

### UTILITIES

Typically utility consumption of a SCOT unit per ton sulfur intake to preceding Claus plant.

Basis: H<sub>2</sub>S content in Claus feed gas : 94% vol.

Electricity	: 28 kWh
L.P. steam consumption	: 0.46 t (for add-on SCOT)
L.P. steam production	: 0.33 t (for integrated SCOT)
Fuel gas	: 0.016 t
Boiler feed water	: 0.36 t

### FEATURES

- ☆ High degree of desulfurization over a wide range of operating conditions.
- ☆ Recovery of sulfur as a single, homogeneous product via the Claus unit.
- ☆ No secondary air or water pollution.
- ☆ Minimum operator attention.
- ☆ Easy integration with existing Claus units.
- ☆ Application of familiar equipment and process operations.
- ☆ High reliability - less than 1% unscheduled shutdown time.

### REFERENCES

More than 185 SCOT units for the treatment of tail gas from Claus plants ranging in capacity from 3 t/d up to 4000 t/d sulfur production are in operation throughout the world, demonstrating the reliability and flexibility of the process.

### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands, is one of the three authorized licensors on behalf of Shell Research Ltd. since 1981.

# SULFUR RECOVERY

## SPECIALITIES

### 1. JACOBS' NH<sub>3</sub> DESTRUCTION SYSTEM

#### Application

To recover elemental sulfur from acid gas containing H<sub>2</sub>S, CO<sub>2</sub> and NH<sub>3</sub> in Claus plants. In JNL's ammonia destruction system all gases containing H<sub>2</sub>S and NH<sub>3</sub> are burnt in one burner, offering the following advantages:

- ☆ Complete destruction of NH<sub>3</sub>.
- ☆ No deposits of ammonia salts.
- ☆ No NO<sub>x</sub> formation due to reducing flame conditions.
- ☆ Simple operation and control.

Since 1969 this Jacobs Nederland system has been installed in more than 150 Claus plants

### 2. HEAVY HYDROCARBON DESTRUCTION SYSTEM

#### Application

Some feed gas streams may contain small amounts of heavy hydrocarbons and aromatics. In Jacobs' burning system, these components are completely burnt, preventing soot formation and the production of off-spec sulfur.

### 3. ABC ADVANCED BURNER CONTROL

#### Application

To control the air to acid gas ratio, the ABC system has to be developed for controlling the H<sub>2</sub>S content in the gas to the SUPERCLAUS<sup>®</sup> reactor stage, but the ABC system can also be applied to control the H<sub>2</sub>S/SO<sub>2</sub> ratio in a conventional Claus plant.

#### Description

To cope with the flow rate disturbances, both the conventional control system and the Advanced Control System (ABC) use a feed-forward (ratio) control scheme. The conventional control system controls the air through the main air valve in ratio to the acid gas flow. It has the disadvantage that the main air valve is big and therefore slow. A step change in acid gas does not result in a step change in the main air flow, and leads to an incorrect ratio during the (long) response time of the main air valve. The ABC system reacts faster to changes in the acid gas flow rate.

The (total) flow controller (FC) manipulates the small (and thus quick) trim air valve, which operates parallel to the big main air valve. To prevent that at a large flow rate disturbance the trim air valve is fully opened or closed, a trim valve position controller is installed, which re-adjusts the trim air valve position by manipulating the main air valve. The second type is a disturbance in the composition of the sour gas. A composition change of the sour gas results in a change in air demand. Both the conventional control scheme as well as the ABC control scheme uses a feedback system to compensate for acid gas composition changes. The conventional control scheme, however, is not able to react adequate on changes in flow rate and gas composition at the same time. The ABC system does not have these disadvantages due to the fact that it actually adjusts the design air to acid gas ratio. A change in acid gas flow rate now results (through the adapted ratio) in the correct air demand, without any further re-adjustment from the quality controller.

### 4. DEEP COOLER

#### Application

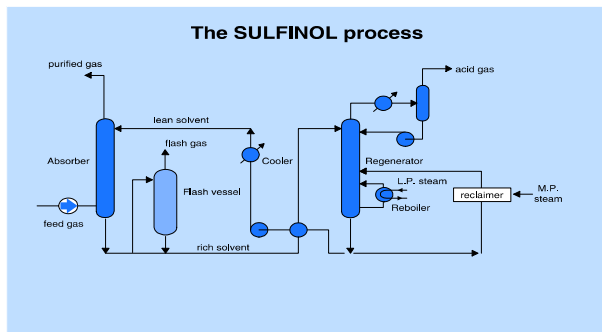
To increase the overall sulfur recovery efficiency by reducing the sulfur vapor losses by cooling the Claus tailgas down to below its solidification point. The Deep Cooler has been developed especially for the SUPERCLAUS<sup>®</sup> process to increase the overall sulfur recovery rate up to 0.3%.

#### Description

A final condensation temperature of 125°C results in sulfur recovery efficiency losses of 0.3% or more. For a SUPERCLAUS<sup>®</sup> unit with a recovery efficiency of 99.0%, these sulfur vapor losses are quite significant. A decrease in the tail gas temperature down to 115°C would result in almost complete recovery of sulfur vapor. Unfortunately, this low temperature is well below the solidification point of sulfur, and consequently solid sulfur is formed in the tubes. The Deep Cooler has been designed for this unconventional cooling and does not plug with solid sulfur. The Deep Cooler has been continuously in operation since September 1994 in a 7 t/d SRU in Germany.

# GAS TREATING (NATURAL GAS / SYNGAS / LNG)

## SULFINOL PROCESS



### APPLICATIONS

The Sulfinol process is a regenerative process developed to reduce H<sub>2</sub>S, CO<sub>2</sub>, COS and mercaptans from gases. The sulfur compounds in the product gas can be reduced to low ppm levels. This process has been developed specifically for treating large quantities of gas, such as natural gas, which are available at elevated pressures.

The Sulfinol process is unique in the class of absorption processes because it uses a mixture of solvents, which allows it to behave as both a chemical and a physical absorption process. The solvent is composed of Sulfolane, DIPA or MDEA and water. The acid gas loading of the Sulfinol solvent is higher and the energy required for its regeneration is lower than those of purely chemical solvents. At the same time it has the advantage over purely physical solvents that severe product specifications can be met more easily and co-absorption of hydrocarbons is relatively low.

The Sulfinol-M process has been developed for selective absorption of H<sub>2</sub>S, COS and mercaptans, while co-absorbing only part of the CO<sub>2</sub>.

Deep removal of CO<sub>2</sub> in LNG plants is another application. Integration of gas treating with the SCOT solvent system is an option.

### DESCRIPTION

The feed gas is contacted counter-currently in an absorption column with the Sulfinol solvent. The regenerated solvent is introduced at the top of the absorber.

The sulfur compounds loaded solvent (rich solvent) is heated by heat exchange with the regenerated solvent and is fed back to the regenerator where it is

further heated and freed of the acid gases with steam. The acid gases removed from the solvent in the regenerator are cooled with air or water, so that the major part of the water vapor they contain is condensed. The sour condensate is reintroduced into the system as a reflux. The acid gas is passed to the sulfur recovery plant (Claus plant) in which elemental sulfur is recovered. The application of a flash vessel is optional; it depends on the heavier hydrocarbon content of the feed gas. The application of a reclaimer is also optional and depends on the amount of non-regenerative compounds in the solvent.

### OPERATING CONDITIONS

Very wide ranges of treating pressures and contaminant concentrations can be accommodated. Natural gas pipeline specifications are easily met. Removal of organic sulfur compounds is usually accomplished by the solvent circulations as set by H<sub>2</sub>S and CO<sub>2</sub>. In LNG plants a specification of 50 ppm CO<sub>2</sub> prior to liquefaction is attained without difficulty.

### UTILITIES

The utility consumption varies widely with feed gas composition and product gas specification.

### FEATURES

- ☆ Removal of H<sub>2</sub>S, COS and organic sulfur to natural gas pipeline specification.
- ☆ Low steam consumption and solvent circulation.
- ☆ Low corrosion rates.
- ☆ Selective removal of H<sub>2</sub>S in some natural gas applications.
- ☆ Smaller equipment due to low foaming tendency.
- ☆ High on-stream factor.

### REFERENCES

More than 200 Sulfinol units ranging in capacity from 10.000 Nm<sup>3</sup>/d to 32.000.000 Nm<sup>3</sup>/d are in operation throughout the world, demonstrating the reliability of the process.

### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands, is one of the three authorized licensors on behalf of Shell Research Ltd. since 1981.

Streams to be treated	Contaminants removed
Natural gases	H <sub>2</sub> S, CO <sub>2</sub> , COS, RSH + organic S
Oil and coal gasification	H <sub>2</sub> S, COS (H <sub>2</sub> S is selectively removed)
Natural gases	H <sub>2</sub> S, CO <sub>2</sub> (partly)
LNG feedstock, hydrogen manufacture synthesis gas	CO <sub>2</sub>

# SULFUR ASSESSMENT STUDY

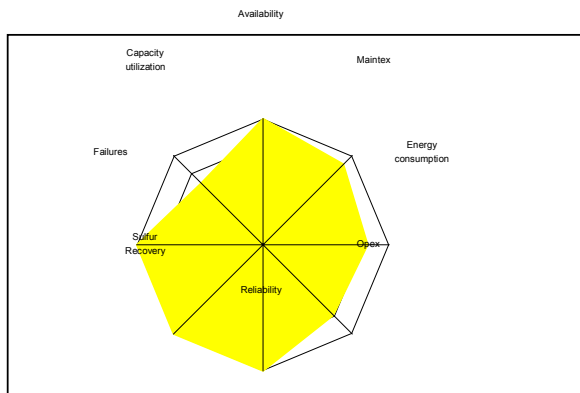
## INTRODUCTION

Jacobs Nederland B.V. (JNL) has a wide experience in designing, engineering and constructing sulfur plants (with and without tail gas treatment). Therefore, JNL has the unique position to combine the operational experiences from several sulfur plant owners. To improve the performance of the plants of our existing clients and to establish the exchange of experiences, JNL has developed the Sulfur Assessment Study.

The main objective of the Study is to measure and improve plant performance by:

- Comparing the performance in a benchmark.
- Giving plant specific advice.

SULFUR PLANT PERFORMANCE BENCHMARK 1999  
Balanced score card representing the highest scores of the participants



## DESCRIPTION

The topics, which are addressed, are:

- **Organizational aspects:** shifts, training.
- **Plant data:** performances of equipment, catalyst, areas of modification, utility consumption, operating costs, feed data, recovery, analysis.
- **Operational aspects:** operation modes, reliability/availability, capacity usage, problem areas, procedures, safety.
- **Instrumentation:** plant automation systems, critical instrumentation, analyzers.
- **Inspection/maintenance:** techniques, costs, organization of turnarounds, critical maintenance areas, corrosion.
- **Environmental aspects:** authority requirements, SO<sub>2</sub> emissions, penalties, waste disposal.
- **Future developments:** operation modes, plant capacity, environmental requirements.

## PROCEDURE

After a positive reaction on the invitation letter, the clients receive a questionnaire concerning the above described topics, followed by a plant visit with discussions during 2-3 days. The results are described in a benchmarking report, followed by a client specific report. The presentation of the benchmark as well as the exchange of experiences of the clients will be facilitated during a workshop in our office.

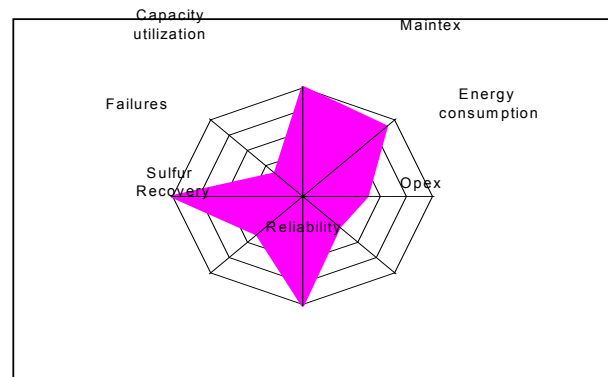
## BENCHMARK

The benchmark is executed via defined performance indicators, which are combined in the benchmarking index. The performance indicators for this study are:

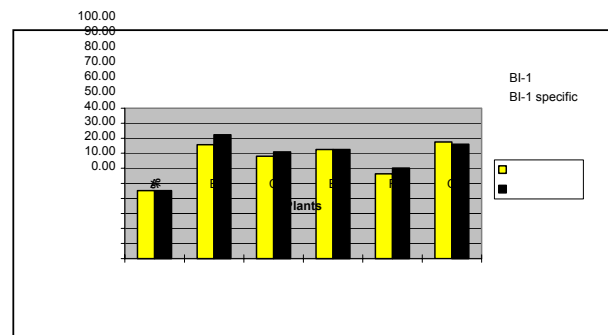
- Availability
- Maintenance expenses
- Energy consumption
- Operational expenses
- Reliability
- Sulfur recovery
- Failures
- Capacity utilization

## PRESENTATION OF THE RESULTS

- Selective best performance: the participants are ranked on each specific performance indicator.



- Overall best performance: This is determined via the benchmarking index, which is a weighted average of all the performance indicators.



## EXPERIENCE EXCHANGE

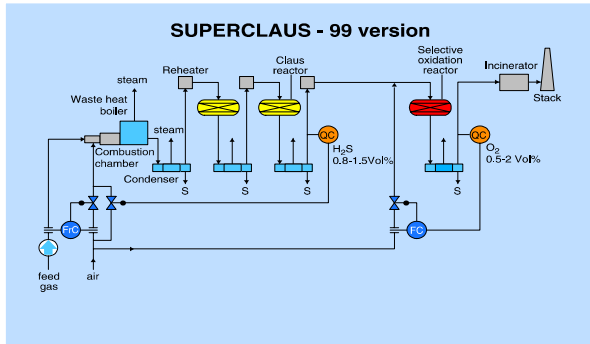
An indication of the topics that were discussed during the last study: corrosion, waste heat boiler tube sheet corrosion, inspection techniques for HIC detection, capacity increase, problems with tail gas analyzers, foaming, hydrocarbon carry-over, gas sampling techniques, shutdown procedure.

## REFERENCES

In the past studies major West European refineries have participated.

# SULFUR RECOVERY

## SUPERCLAUS® PROCESS



### APPLICATIONS

The SUPERCLAUS® process has been developed to recover elemental sulfur from H<sub>2</sub>S containing gases originating from gas treating plants such as alkanolamine units or physical solvent plants. Modern SUPERCLAUS® plants should be able to process H<sub>2</sub>S/NH<sub>3</sub> containing gases as well, originating from Sour Water Strippers, with the objection to yield up to 99.4% overall sulfur recovery without any further tail gas clean-up.

### DESCRIPTION

The SUPERCLAUS® process consists of a thermal stage followed by three catalytic reaction stages with sulfur removed between stages by condensers. Two reactors are filled with standard Claus catalyst while the last reactor is filled with the new selective oxidation catalyst. In the thermal stage, the acid gas is burned with a substoichiometric amount of controlled combustion air such that the tail gas leaving the second reactor contains typically 0.8 to 1.0 vol.% of H<sub>2</sub>S. The new catalyst in the third reactor oxidizes the H<sub>2</sub>S to sulfur at an efficiency of more than 85%. However, because the new catalyst neither oxidizes H<sub>2</sub>S to SO<sub>2</sub> and H<sub>2</sub>O nor reverses the reaction of sulfur and water to H<sub>2</sub>S and SO<sub>2</sub>, a total sulfur recovery efficiency up to 99% can be obtained. If a sulfur recovery rate of more than 99% is required, one additional Claus reactor stage will be installed upstream of the selective oxidation reactor.

### OPERATING CONDITIONS

Two main principles are applied in operating the SUPERCLAUS® process:

- ☆ Operating the Claus plant with excess H<sub>2</sub>S to suppress the SO<sub>2</sub> content in the Claus tail gas.
- ☆ Selective oxidation of the remaining H<sub>2</sub>S in the Claus tail gas by means of special catalyst which

efficiently converts the remaining H<sub>2</sub>S in the presence of water vapor and excess oxygen to elemental sulfur only.

- ☆ Other operating features, which apply to Jacobs' Claus process, are applicable for the SUPERCLAUS® process as well, such as NH<sub>3</sub> destruction up to 30 vol.%, the capability to process small amounts of heavy hydrocarbons and aromatics up to 2 vol.%, turndown ratios of 100-15% and production of 99.9% pure bright yellow sulfur.

### UTILITIES

Basis: 100 t/d sulfur recovery unit, 93 vol.% H<sub>2</sub>S feed gas and catalytic incineration.

		Consumption	Production
LP steam	t/h	--	3.3
MP steam	t/h	--	10.2
Electricity	kW	220	--
Fuel gas	t/h	0.12	--
Boiler feed water	t/h	13.5	--
LP steam (plant heating)	t/h	0.4	--

### FEATURES

- ☆ Application in both new and existing plants.
- ☆ The newly developed SUPERCLAUS® catalyst possesses some unique properties:
  - oxidation of H<sub>2</sub>S to sulfur is complete
  - no sensitivity to water vapor
  - further oxidation of SO<sub>2</sub> is negligible even in the presence of excess oxygen
  - components such as H<sub>2</sub>, CO and other combustibles are not affected
  - the catalyst does not promote the Claus equilibrium reaction
- ☆ Long catalyst lifetime up to 10 years.
- ☆ Sulfur recovery up to 99.4%.
- ☆ Reduction of current SO<sub>2</sub> emissions up to 90%.
- ☆ Simple continuous operation.
- ☆ Low additional investment costs.
- ☆ NH<sub>3</sub> destruction.
- ☆ Capability to combust heavy hydrocarbon and aromatics.
- ☆ High turndown.
- ☆ High reliability - less than 1% unscheduled shutdown time.

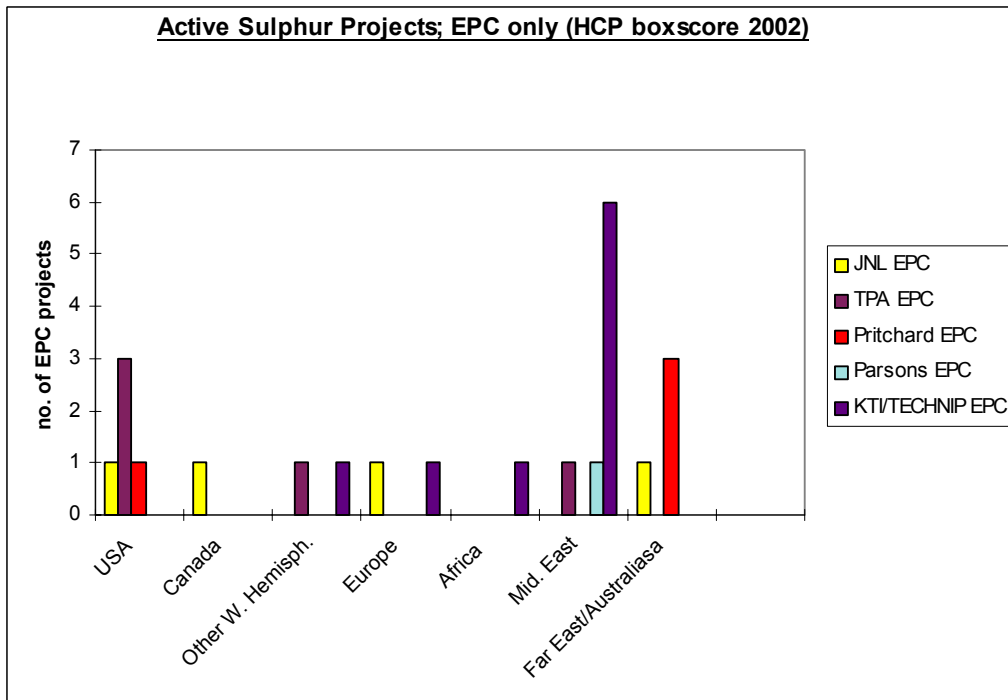
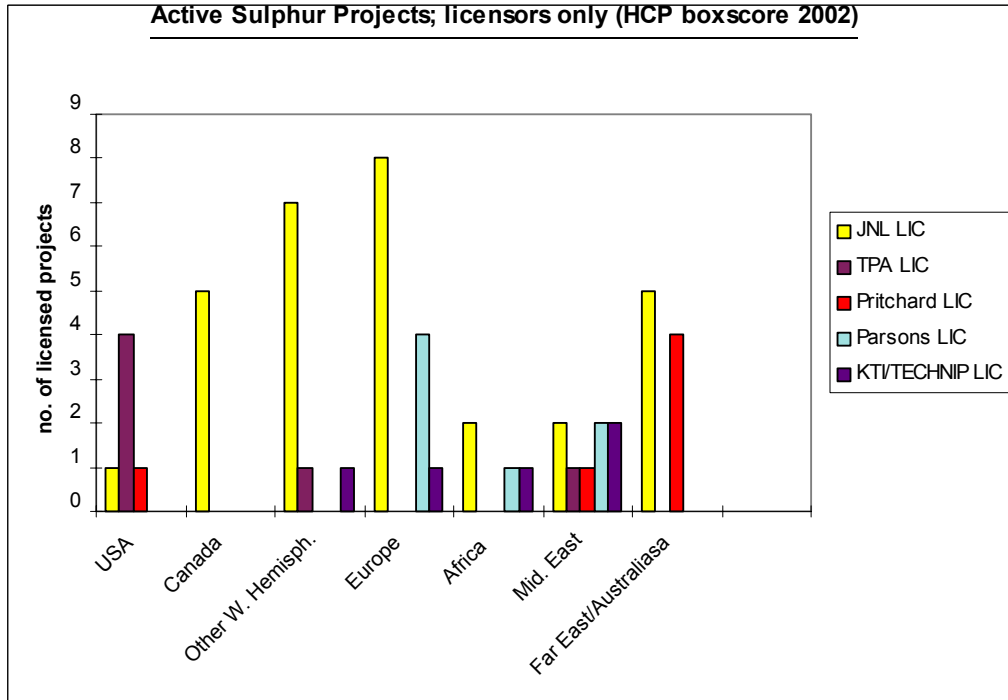
### REFERENCES

Since the first commercial demonstration of the SUPERCLAUS® process in 1988, more than 110 plants with a capacity up to 1165 t/d are in operation or under construction in the first quarter of 2003.

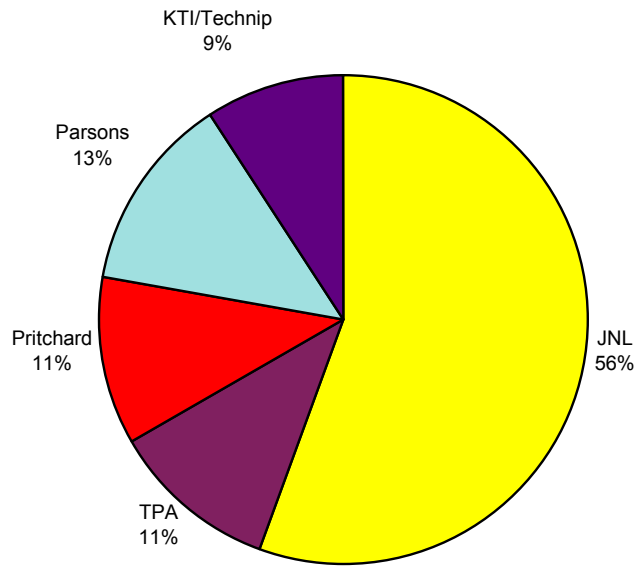
### LICENSOR

Jacobs Nederland B.V., Leiden, The Netherlands.

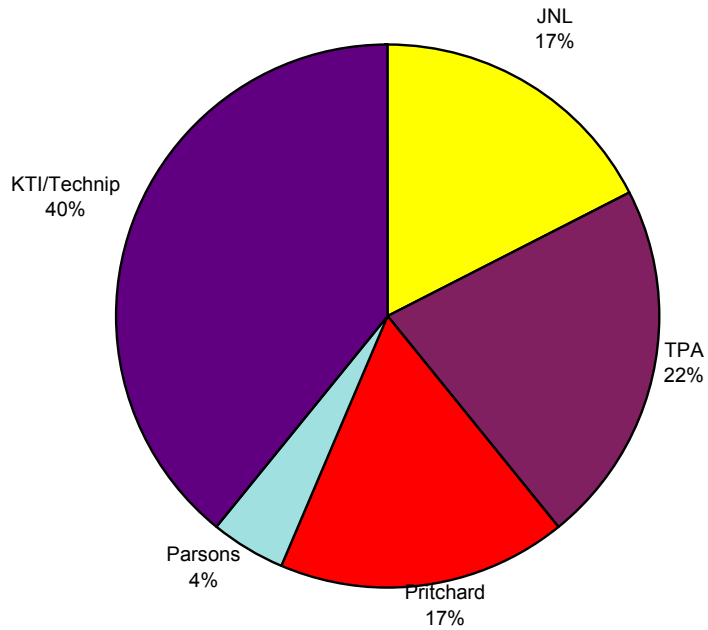
Box Score Sulfur Recovery Projects



**Major licensors**



**Major eng. contractors**



Box Score Sulfur Recovery Projects

