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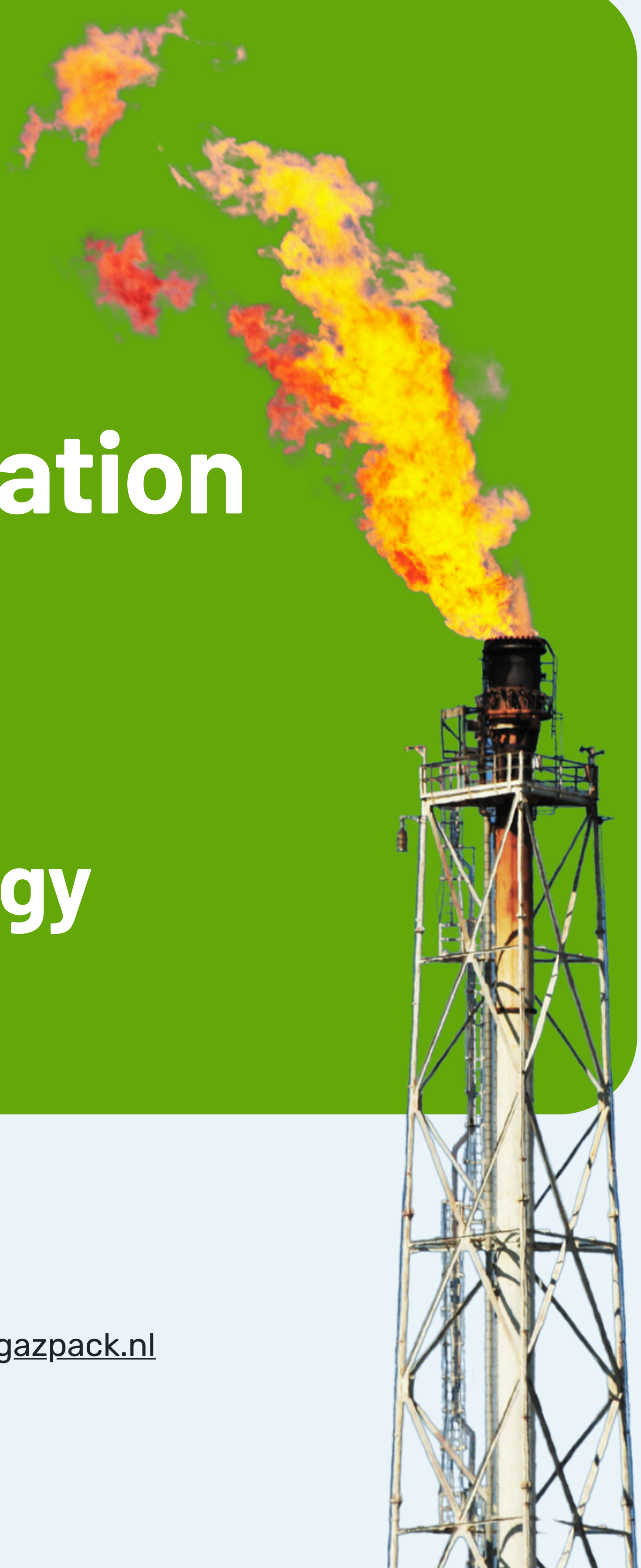
WHITE PAPER

Flare Desulfurization

A Promising Solution for Cleaner Energy



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Flare Desulfurization

Energy production finds itself under enormous pressure in the 21st century. Economic pressure comes from increasing demand. Social pressure results from a greater interest in environmental sustainability. These combine to form political pressure in regulation, subsidies, and penalties.

While research and development in cleaner emissions are ongoing, industry efforts to minimize the contaminants radiating from power, oil gas, and natural gas deposits represent longstanding practices that respond to expanding knowledge in this area. Flaring is one such measure that burns off concentrated gases at oil drilling sites, separating sulfuric compounds from petroleum.

The Presence of Sulfur

Sulfur is one of the most commonly occurring elements in the known universe. This is fortunate because humanity finds many uses for this versatile substance. From weedkillers, insecticides, and fertilizers for farming to nutritional supplements, food preservatives, and chemical cleansers in households, sulfur is omnipresent in manufactured products. In addition, it is abundant in the crust of the earth, as well as many varieties of flora and fauna. Consumers of grapefruit, for example, are eating volatile sulfur compounds. However, this does not mean that all such compounds are benign and useful.

Sulfur compounds in petroleum include:

- **Thiophenes** look (in liquid form), react, and smell like benzene. They can occur in petroleum in concentrations ranging from one to three percent. Also present in coal, thiophenes are believed to occur naturally on Mars.
- **Sulfides** are a broad category that refers to any compound of sulfur and another element.
- **Thiols** – are sulfur-containing organic compounds that bear a strong resemblance to alcohols. Thiols are known for the odors emanating from garlic and the spray of skunks.
- **Sulfoxides** – when sulfur and oxygen bond, the organic compounds that result fall under the category of sulfoxides. Topical drugs often contain sulfoxides, as do skin protective agents used in cryopreservation.
- **Sulfones** – are organic sulfur compounds where two carbon atoms are present. Central to the composition of acrylics, medical instruments, aerospace equipment, and food technology, sulfones compose many household goods.

Solid or liquid sulfur is relatively safe for humans and nature. Any toxicity the element may present comes in only the highest concentrations of sulfur, and that damage is often minor, e.g., coughing, slight skin irritations, and temporary visual impairment. Gaseous sulfur can be more of a hazard, particularly since it is colorless, although often detectable by smell. Those working with chemicals and their compounds -- using pesticides and herbicides, for instance — take necessary precautions with protective covering when dealing with pure sulfur and its derivatives.

Sulfur is widely used and a boon to industry, technology, and the overall economy. Desulfurization of petroleum does not imply that the element is to be universally avoided. In fact, much of the sulfur extracted from oil deposits ends up in some of the applications named above. Still, sulfur compounds in petroleum and natural gas are problematic in the production and use of these energy sources.

When Is Sulfur Harmful?

When fossil-based energy sources combust, chemical reactions ensue, and volatile sulfur compounds form. One such chemical is sulfur dioxide (SO_2). It can pollute the atmosphere as fine particles as well as a gas. These particulates are carried over hundreds of miles by wind. Public health consequences of this distribution are manifest as wheezing, coughing, shortness of breath, and feelings of compactness in the chest. Over the long term, exposure can grow into severe respiratory pathologies, especially for those with pre-existing conditions. SO_2 is present at its highest intensity where coal-fired production sites are located.

Of even greater concern is hydrogen sulfide (H_2S). Also known as sewer gas or swamp gas, H_2S is a byproduct of not only oil/gas refining but also mining of various ores, the production of paper and related pulp, and the manufacturing of rayon fabrics. Given its alternate names, this substance occurs naturally in sewers, manure lagoons, wells for water, and deposits of fossil fuels. Since it is of a greater mass than air, H_2S tends to lie low, as these locales demonstrate. Yet its tendency to occupy deep and confined places provides danger to energy workers and adjacent areas.

Those working near hydrogen sulfide – even in low concentrations – can experience breathing problems, headaches, visual issues, and other irritations. On the more serious end of the spectrum, they can lose consciousness or even life. Beyond the thoracic problems, H_2S is very flammable and can cause explosions under certain circumstances. As it subsequently burns, hydrogen sulfide gives rise to **other toxic contaminants**. Contact with H_2S in liquid form can affect the equivalent of frostbite on the skin. The gas, meanwhile, has a reputation for causing dizziness that ends in injury.

The health threats posed by volatile organic sulfur compounds are not the only negatives with which to contend. Unless removed from petroleum or another energy medium, sulfuric compounds diminish the capacity to generate power. In diesel engines the presence of sulfur notably hastens corrosive wear in crucial components like piston rings and cylinder liners. In addition, fuel injection systems can clog, and combustion suffers from diminished efficiency when sulfuric compounds are not sufficiently removed from fuel.
Plus, its tendency to induce corrosion makes H_2S a damaging agent for transport pipelines as well as storage tanks.

The issues summarized here underscore the difficulties that sulfuric compounds add to the refining and production process in the oil and gas industry. Their flammability represents the most potentially catastrophic outcomes. The accumulated pressure that might come from human activity or elsewhere demands a relief valve of sorts to release unwanted gases and stabilize the extraction and production environments. This is why flaring serves as a central practice: not only to rid the product of contaminant gases but also to effectuate a safe working environment for those on-site. In so doing, though, and like all solutions, flaring brings its side effects.

The Process of Flaring

Prior to the process of flaring, the infrastructure is cleansed with nitrogen. Because this element neither reacts easily to chemical compounds nor combusts without difficulty – and because it effectively displaces both water and oxygen – **nitrogen is an optimal purification medium** when the flare is between jobs. It provides the safest and most advantageous conditions for the delicate work of cleansing gas or oil of sulfuric gases.

Unrefined oil or gas passes through a screw compressor that operates with a mechanism comprised of two rotors that mesh together. These components work on the principle of positive displacement to compress the oil or gas – the close seal between the rotors traps the gas, thereby decreasing its volume – whereby the substance passing through is taken in and expelled. Prior to this process, any water vapor present is removed. **This leaves a purer energy source** that occupies less space. Sometimes, this is known as drying the oil or gas that passes through.

The compression of the gas or oil applies up to 10 bar(a) pressure, with one bar equaling approximately the atmospheric pressure on the earth at sea level. Reducing the volume **makes the energy more amenable to transport and storage**. Should the gas be reserved for vehicle fuel, a diaphragm compressor is sometimes an option. Here, a flexible membrane is the medium of intake for the gas. Whether reciprocating, screw, or diaphragm compressor, this step is necessary prior to desulfurization.

Sulfur removal precedes flaring, and the process should be executed carefully for petroleum, natural gas, and biogas. For natural gas, the extraction of H_2S is paramount because of the havoc it wreaks on pipelines and other conduits and the physical threat it poses to workers and end-users. Removal is important in the case of petroleum for similar reasons and for the sake of environmental health. Even biogas comes with hazardous H_2S that menaces transport channels, storage vessels, and industry workers. There are **multiple procedures for achieving the hydrogen sulfide separation goal** outlined below.

The good news is that very little H_2S is left following the flaring process. The United States Environmental Protection Agency (EPA) asserts that 98 percent of unwelcome compounds are eliminated when fuel-air mixture and flame temperatures are ideal. This comes after carbon dioxide (CO_2) is captured using specialized membranes. In addition to safety considerations, the exploitation of captured gases is an economic plus associated with flaring when all is said and done.

In a typical flare system, a header then receives this cleansed gas while a knockout drum receives and retains the resulting condensed liquids. A proprietary seal or, alternatively, a **purge gas supply prevents flashback**, i.e., the influx of air that would otherwise disrupt the flow to the burn unit and flare stack. Ignition or pilot components push the waste gases through the stack. For combustion to occur, fuel, oxygen, and heat must be derived from the ignition.

What Are Some Objections to Flaring?

The safety and efficiency benefits of flaring motivate its general practice in the energy industry. Yet, there are voices in the culture and policy realm that highlight the cons of flaring against the pros. For example, flaring releases methane (CH_4) into the atmosphere. Also, CO_2 escapes through flaring. Both of these are greenhouse gases that are **atmospheric villains in the climate change narrative.** Yet, these are invisible culprits. Flare stacks also release "black carbon," that particulate matter that goes by the alias of soot. While its tenure in the atmosphere is brief, its damaging effects on floral, faunal, and human health are lasting.

Although methane is less abundant in the atmosphere than carbon dioxide and remains in the earth's envelope for a smaller duration, it nevertheless – molecule for molecule – traps more heat than CO_2. Sources of methane related to human activity include agricultural livestock, motor vehicles, and landfills. Naturally occurring CH_4 emanations often rise from bogs and wetlands. Government agencies tracking methane estimate a 20 to 30 percent increase in atmospheric concentration since the Industrial Revolution. With all this acknowledged, **measuring CH_4 presence is a longstanding challenge in the atmosphere**. Instead, researchers would inventory cattle herds, wellheads, and coal mines to make a determination. More recently, satellite technology has allowed for a clearer valuation of CH_4 concentrations around the world. After CO_2, it is a major contributor to global warming.

Carbon dioxide is, of course, the most notorious of the greenhouse gases. Prominently linked to the burning of fossil fuels, CO_2 has increased to 36.6 billion tons annually by the most recent measurements. The natural receptors of CO_2 – forests, grasslands, pastures, and oceans, for example – are now overwhelmed and cannot absorb all the gas emitted. Once released, CO_2 absorbs the heat from the earth's surface and disperses the heat at every angle, including back toward the earth. **In so doing, it raises the temperature of the planet and the acidity of its oceans.**

Soot particles ejected from flare combustion can actually alter the formation of clouds. This affects the climate by consuming the **short-wave radiation from the sun**. Additionally, black carbon particulates damage the respiratory health of humans and animals while diminishing the health of the soil. All in all, the problems that stem from flaring should not be ignored. However, neither are they intractable. The waste and pollution that make the practice vulnerable to these criticisms are on the decline against the advance of new and better technologies.

Research and development projects, sponsored by government and private entities, focus on converting some previously emitted compounds into mobile, economically beneficial substances like hydrogen, ammonia, and solid carbon. Separating contaminants from the flow ahead of combustion, as with desulfurization, complements efforts to mitigate the combusted gases from the flaring process.

Methods for Desulfurization

Hydrogen sulfide and sulfur dioxide are released through the energy production process, from extraction to transportation to storage to processing and refinement. Such applications include:

1. Wet scrubbing – This is when the gas is sprayed with a wet substance, such as water or selected chemicals. The contaminating gas or particulate matter binds to the "scrubbing liquid" mist, leaving the natural gas, biogas, or other energy medium cleaner than before. Sometimes, this application uses mist to pervade the gases; in other instances, the gas moves through a liquid pool that accomplishes the same result.

2. Spray-drying – This aims to convert the H_2S or SO_2 into a dry powder to remove it from the flow leading to combustion. Utilizing hot air and high pressure, this procedure – also known as atomization – is also common in the production of pharmaceuticals.

3. Wet sulfuric acid process – Here, high-pressure steam yields combustion, oxidation, hydration, and condensation to create sulfuric acid,a versatile and profitable compound found in many industries, like metallurgy and viscose.

4. SNOX flue gas desulfurization – Similar to the above result, except that nitrogen oxide is an additional formation that results from this process.

Several different chemicals are useful in separating H_2S. Amines, for example, are compounds where one nitrogen atom with a lone pair of electrons is combined with other elements using hydrogen bonding. They are derived from ammonia. Also present in dyes and drugs, this class of chemicals is frequently employed to capture H_2S and CO_2 in the gas, oil, and fuel industries. Alkylamines also come from ammonia; this time, the organic compound forms when one or more hydrogen atoms are replaced. They form stable and soluble compounds that are efficiently removed from the gas flow. Aside from their powers to pull H_2S from gas streams, alkylamines contribute to the production of rubber, surface disinfectants, and pesticides. Other compounds are successful at desulfurization yet yield poor side effects like equipment corrosion and leaving unwanted solids such as sludge.

5. Molecular Sieve - 5. One of the most advanced separation technologies is based on old principles. Basically, working like a strainer, a carbon molecular sieve possesses scalable membranes that allow the natural gas molecules to pass through the permeable surfaces while capturing the hydrogen sulfide particles. Composed of long, multiple-unit molecules, the polymers that make up the membrane fabric are both cross-linkable and kinked in structure. This means they are made of repeating units and are linked by ionic or covalent bonds. Such structures occur naturally in fibers like silk and wool. Plus, they can be engineered and incorporated into clothing, auto parts, kitchen utensils, and carpeting.

With pores that are uniform in dimension, the molecular sieve operates on the principle of adsorption: when the H_2S molecules adhere to the fabric surface as purer gas flows through the pores. This has an advantage over absorption, where the H_2S would saturate the filtering material. Instead, the sieve is reusable as the surfaces are cleansed and available for successive applications. Meanwhile, the once destructive H_2S is modified through the application of heat and water to make sulfuric acid -- an essential component of batteries. Adsorption methods are environmentally accommodating and efficient at cleansing natural gas emissions from flares and elsewhere.

Conclusion

Of course, need, capacity, and energy medium will determine whatever option of gas separation is most appropriate, but the molecular sieve is long on benefits and short on drawbacks. Biogas producers are now faced with the same decision. Capturing methane through the anaerobic digestion of organic matter, biogas companies look to **convert raw biogas to usable biomethane**, requiring the removal of toxic or unwanted chemical compounds. The nearly two-decade-old Gazpack company continues to perfect the separation process, leaving no waste behind. To that end, Gazpack developed its Sulaway unit.

Sulaway's purpose is to convert high volumes of raw biogas to biomethane. At the same time, it is adaptable to modest capacities as well. The purity of its biomethane output measures is **consistently at/or about 99.5 percent**. Given this degree of cleanness, the Sulaway biomethane is fit for injection into the natural gas grid. In addition to turning hydrogen sulfide into sulfuric acid, this unit also efficiently captures CO_2, which gets liquefied and sold to a variety of industries. Few choices in industry -- or life -- allow for win-win scenarios. Gazpack's **Sulaway system** is one of them.

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