Alternative Sulfur Management Solutions
to Help Refiners Meet Clean Fuel and Environmental Challenges

Eric Ye
Technical Development Manager
DuPont Refining Solutions
Barley Mill Plaza
4417 Lancaster Pike
Wilmington, DE
United States of America
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ABSTRACT

The rapidly expanding world economies, especially those in the Asia-Pacific region, have resulted in a sharp increase in energy demand. Much of this energy demand is projected to come from oil, which is increasingly becoming more “sour” or greater in sulfur content. At the same time the world’s regulatory agencies are enacting increasingly stringent environmental regulations. These regulations not only apply to emissions from the refining complex itself, but on the products produced by the refinery as well. These regulatory and market dynamics have created a challenging environment for a refiner to operate in, especially with respect to recovery and disposition of sulfur (sulfur management). This paper reviews the market and regulatory dynamics affecting the world’s petroleum refining industry and summarizes the challenges it faces. It also discusses the projected future sulfur supply and demand imbalance and how this will affect the refiners and sulfur merchants. In addition, the paper will explore an alternative, holistic approach to meeting these challenges that provides an environmentally friendly, cost effective, and commercially proven solution with respect to refiners sulfur management and clean fuel challenges.

INTRODUCTION

The world’s economies, especially those in the Asia Pacific region, have entered a period of unprecedented growth. The United States Energy Information Administration (EIA) estimates that the world’s economies will continue to grow at a rate of 4.2% until 2010 before leveling off at a rate of 3.7% until 2025. This economic growth requires increasing amounts of energy. Despite recent activity into alternative energy sources, oil, coal, and natural gas remain the dominant source of energy for the world. Current EIA projections estimate that the consumption of crude oil will parallel the rise in world gross domestic product (GDP) increasing by a rate of 2.5% per year to 2010 before leveling off at 1.5% per year until 2025.

While most analysts agree that the current supply of oil is sufficient to meet this energy demand, the quality of the crude will increasingly become heavier and greater in sulfur content. The deteriorating quality of crude presents a challenge to today’s refiners.

This rapid growth has unfortunately resulted in the deterioration of the environment in various parts of the world. In response, the governments and regulatory agencies of the world are enacting increasingly more stringent regulations with regard to not only industrial emissions, but emissions from mobile sources (vehicles) as well. Much of the focus of these environmental regulations have been to reduce levels of such contaminants such as SOx, NOx, Volatile Organic Compounds (VOC), Carbon Monoxide (CO), and Particulate Matter (PM).

The reduction of emissions of these various contaminants from mobile sources is especially challenging as a number of variables effect the emissions from these vehicles. Aside from the design of the vehicle itself, fuel quality is a major factor in the amount of regulated emissions from a vehicle. Extensive research has proven that reducing the sulfur content of gasoline or diesel significantly reduces the level of regulated contaminants from a vehicles exhaust. With respect to gasoline, it has also been found that reducing the levels of compounds such as aromatics and olefins, further reduced the emissions from a vehicle.
Based on these findings regulatory agencies around the world are restricting the level of these compounds in transportation fuels. For a refinery blending gasoline, not only has this increased the level of investment required to continue to operate, but the restriction of high octane compounds such as aromatics and olefins has created a shortage of octane in the world’s gasoline blend pool.

While the market for clean transportation fuels has been growing at a rapid pace, the market for sulfur and sulfur derivatives is projected to be unable to keep up with the production. In the next five to six years, an additional 11.6 million metric tons per year of recovered sulfur from crude refining and liquefied natural gas (LNG) projects are expected to result in an 18% increase in the total sulfur and sulfur derivative supply. Clearly, this sulfur market imbalance will make the disposition of elemental sulfur a significant challenge for many of the world’s petroleum refiners and sulfur merchants.

In summary, these particular changes in the market and regulatory environment, have created a growing need for solutions to the following petroleum refining challenges.

∞ The production of high octane gasoline blend components low in levels of aromatics, olefins, and sulfur.
∞ An effective and economically attractive means of reducing point source (stack) emissions of SOx, NOx, VOC, CO, and PM.
∞ The recovery of additional sulfur, and the marketing or disposition of this incremental produced sulfur in an increasing challenging environment.

While there are a number of existing technologies and methods to address these issues, for a specific refiner, an integrated solution utilizing sulfuric acid production, alkylation, and even regenerative scrubbing system can provide an optimal solution to the refiner in meeting these challenges. Such a solution is already practiced by DuPont in the United States and has provided these refiners with optimum solution to their sulfur management and clean fuel challenges.

MAIN BODY

CHALLENGES FACING THE WORLD REFINERS

Virtually no one in the world consumes raw crude from the well, rather the crude must be processed or refined into various finished products prior to consumption. Each refinery is unique and more often than not is designed for a specific type or types of crude. Much of the existing refining capacity in the world today has been designed to process what is referred to as light “sweet” (less than 1.0 wt% sulfur) crudes. These types of crudes are low in sulfur and yield, with minimal processing, highly desirable “light” transportation fuels such as gasoline and diesel.

While most industry analysts believe that there is a sufficient supply of crude oil available to meet the world’s growing energy demand, the quality of crude that is available to the refinery is declining. Though new discoveries of sweet crude are being made, these discoveries are at best only sufficient to counter the decline in production from the mature light sweet crude fields. The additional crude supply come from medium or heavy sour crude from sources such as the oil sands in...
Canada, heavy oils from Venezuela and sour crudes from the Middle East. This trend is illustrated in figure 1.

Figure 1
Global Sweet Sour Crude Production

Figure 2, illustrates the net result of this crude quality decline trend. As shown, the crude quality will increasingly become heavier and higher in sulfur content.

In order to convert heavy sour crudes into salable products, a refiner must make a substantial capital investment, sometimes in the billions of dollars. Such investments include conversion units designed to “upgrade” the heavier components in crude.
Refiners must also make investments to recover the incremental sulfur produced, all while satisfying more stringent environmental regulations for plant emissions and products.

On a simplistic basis, there are two basic environmental regulatory requirements facing today’s refiner.

First, the actual emissions from a refiner are being increasingly regulated. In the United States, Europe, and increasingly the rest of the world, refinery emissions of criteria pollutants (SOx, NOx, PM, CO, VOCs and ozone) are being restricted. To date much of the emphasis to reduce these refinery emissions have focused on the units that emit the largest volumes of flue gas to the atmosphere. In a refinery, these units are often Fluidized Catalytic Crackers (FCCs), Fluidized Cokers, Sulfur Recovery Units (SRUs), and large fired boilers.

A common approach to emission reductions from FCCs and cokers is the addition of a wet gas scrubber or enhancements to existing scrubbers to improve performance. The capability of various technologies to reduce SOx and NOx from FCC flue gas streams has been discussed in recent papers. Generally, once-through caustic scrubbing systems that result in a high total dissolved solids (TDS) discharge stream have been used. With increasing sensitivity to TDS, particularly for inland waterways, the practice of once-through scrubbing may come under pressure. Such inland refineries may need to convert to either regenerative or recycle/reuse systems.

Secondly, the emissions of these same criteria pollutants generated by the mobile sources (vehicles) that consume a refiner’s products are also coming under stringent regulation. The solutions to comply with these regulations involve a detailed discussion on engine design and fuels formulation, topics that are beyond the scope of this paper. However, the net result is that certain compounds are increasingly being restricted in the refinery product pool. Actual fuel quality specifications vary from country to country and in some cases vary significantly within regions of a particular country. However, outside of the United States, most developing countries are adopting the European specifications as these specifications are more straightforward than the multitude of US regulations.

With respect to transportation fuel quality, sulfur is a particularly objectionable compound. As a result, sulfur levels are being restricted in all transportation fuel including gasoline, diesel, and heavy oils (resid and bunker fuel). Tables 1 and 2 are a selection of a few of the world’s countries gasoline and diesel sulfur specifications and the regulatory timetable associated with these specifications. As can be seen, sulfur levels in gasoline and diesel are, for all extent and purposes (in most mature economies) will effectively be reduced to zero by 2010. The rest of the world will not be far behind in also eliminating the sulfur content from their transportation fuels.
Fuel specifications as they apply to gasoline, provide a special challenge to today’s refiner. Aside from restricting sulfur compounds in gasoline, compounds such as aromatics, olefins, and light hydrocarbons are also being restricted in the gasoline as these compounds have been found to increase emissions of particulate matter and objectionable VOCs. Many of these compounds are high in octane. By restricting their levels in the refining gasoline pool, the refiner is left with an octane shortage and in some cases an inability to find alternative markets for the light hydrocarbons such as butanes and pentanes that used to be blended into the gasoline pool.
In the United States, this situation has been aggravated by the effective banning of methyl tertiary butyl ether (MTBE) in the gasoline pool. Not only did MTBE (109 blending octane) provide a significant source of octane to the gasoline pool, it also consumed a large volume of isobutylene, which refiners can only blend into the gasoline on a limited basis.

Adding to this burden of upgrading a refinery to process lower quality crudes, producing increasingly higher quality product, and increasingly stringent environmental regulations is the lack of resources available to a refiner to implement their solutions to these issues. Both material and skilled workers that have the specific skill to manufacture, build, and operate new refinery processing units are limited, a result of several decades of under investment in the refining industry. As a result, the refiner is faced with an additional challenge that of an inflationary environment specific to this industry and the lack of skilled manpower to operate these in a safe, reliable, profitable, and environmentally sound manner.

**IMPACT ON THE WORLD SULFUR AND SULFURIC ACID MARKETS**

The net effect of these changes in the world crude demand, crude quality, and refined product specification will have a monumental impact on the world’s sulfur supply and therefore on the sulfur supply and demand balance.

Figure 3, summarizes the current world sulfur production and the impacts these changes to the world’s petroleum refining environment will have on the sulfur production in the next five years⁶. As can be seen, the additional recovered sulfur from refining operations is expected to increase the world’s sulfur supply by 6.7 million tons per year or nearly 10%. Adding to this production are a number of very large liquefied natural gas (LNG) projects in Qatar (Ras Laffan), the UAE (Habshan, Asab, and Ruwais), and Saudi Arabia (Berri) scheduled to come on line in 2008. These projects alone are estimated to add another 5.9 million tons/yr to the sulfur supply⁷. Incremental oil and gas recovered sulfur is expected to increase the world’s available sulfur supply by 18% in the next five years.

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**Figure 3**

**Sulphur-in-All-Forms Production, 2004**

- Sulphur-in-all-forms (SAF) 69.8 million tonnes
- Brimstone 46.4 million tonnes
- Pyrites 5.7 million tonnes
- sulphur-in-other forms (SOF) 17.7 million tonnes
- crude pyrites
- flotation pyrites
- Smelter acid 15.1 million tonnes
- Others 2.6 million tonnes

- Mined sulphur 0.8 million tonnes
- Native refined sulphur
- Frasch sulphur
- Recovered sulphur 45.6 million tonnes
- Oil 19.6 million tonnes 6.7 million tonnes
- Gas 24.2 million tonnes 5.9 million tonnes
- Others 1.8 million tonnes

* 2004 Sulphur Balance data from British Sulphur Consultants
** 2005 to 2010 incremental production data from Pentasul

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Presented by Eric Ye at The Sulphur Institute’s tenth biennial, international Sulphur Market Symposium, on April 4-6, 2006 in Beijing, China

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Fortunately, for refiners and sulfur merchants alike, the same rapidly growing world economies will result in an increase in sulfuric acid demand. As statistics relating to sulfuric acid consumption can be at times limited, acid consumption projections are subject to assumptions relating to the growth of the numerous sulfur acid end use markets. However, as shown in figure 4, even assuming a healthy sulfuric acid growth rate of 3.2% (similar to the forecasted GDP growth), it is seems clear that worlds markets will be oversupplied.

Figure 4
World Elemental Sulphur Production & Demand

Despite the ability of some major producers of sulfur to store their product indefinitely in remote regions such as the natural gas and oil sands facilities in Canada, the amount of sulfur available on the open market will increasingly exceed the demand. As a result, sulfur disposition by refiners will be become increasingly challenging in an oversupplied environment.

Sulfur management is, with few exceptions, not a core business for the petroleum refiner. From their perspective, these future trends will only reinforce the view that many refiners currently have of the sulfur recovery and management aspect of their business: it is a distraction from their focus on their core business and at worst it is a necessary evil.
Part of the previously noted increased demand for sulfuric acid will come from the petroleum refining industry. As shown figure 5, the petroleum refining industry represents a significant portion of the sulfur demand in the United States\(^9\). The primary use of this sulfuric acid is the production of alkylate, a clean burning high octane blend component that is becoming increasingly popular based on its excellent blending properties for reformulated fuels.

Figure 5

The flow of sulfur in the United States in 2000.

The sources and the industries that consume the sulfur are at opposite ends of the arrow. Data listed are in million metric tons (Mt).

Source: U.S. Geological Survey

For certain refiners, these changes in the market and regulatory environment allow for a unique solution to their sulfur management, environmental and increasingly stringent gasoline challenges.

CLASSIC PETROLEUM REFINERY APPROACH TO SULFUR MANAGEMENT AND CLEAN FUEL CHALLENGES

The classic petroleum refiner approach to sulfur management, clean fuels, and environmental compliance is one of individual solutions to meet each individual challenge. It is a classic case of individually optimized solutions resulting in an overall suboptimized system.

In order to comply with reduced stack emissions, a refiner select from a variety of technologies from various licensors consisting of electrostatic precipitators (ESPs) to remove fines and particulate matter, selective catalytic reduction units or ammonia injection to reduce NOx emissions, and wet gas scrubbers to reduce SOx emissions.
In order to enhance their gasoline pool, a refiner can choose from a variety of options, each with its own benefits and applications. Table 3, summarizes just a few of the potential blendstocks and their properties that can be produced by a refiner to help meet their clean fuel demands.

### Table 3
**Gasoline Blendstock Characteristics for Automobile Emissions Reductions**

<table>
<thead>
<tr>
<th>Component</th>
<th>Octane</th>
<th>RVP (PSI)</th>
<th>Sulfur Content</th>
<th>Aromatic Content</th>
<th>Olefin Content</th>
<th>Yield Vol. Prod/Vol. Olefin Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkylate</td>
<td>93</td>
<td>4</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>1.70</td>
</tr>
<tr>
<td>MTBE</td>
<td>109</td>
<td>8</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>1.25</td>
</tr>
<tr>
<td>ETBE</td>
<td>111</td>
<td>4</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>1.44</td>
</tr>
<tr>
<td>Isomerate</td>
<td>84</td>
<td>14</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Isooctane</td>
<td>99</td>
<td>2.5</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0.85</td>
</tr>
<tr>
<td>Isooctene</td>
<td>101</td>
<td>2.5</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>100%</td>
</tr>
<tr>
<td>Cat Poly Gasoline</td>
<td>90</td>
<td>9</td>
<td>Trace</td>
<td>None</td>
<td>100%</td>
<td>0.80</td>
</tr>
<tr>
<td>Ethanol</td>
<td>114</td>
<td>20</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Reformate</td>
<td>93</td>
<td>3</td>
<td>None</td>
<td>Moderate</td>
<td>Trace</td>
<td>N/A</td>
</tr>
</tbody>
</table>

However, one such choice that has proven to be particularly attractive to US refiners is alkylate. Alkylate is produced by combining a light olefin molecules (C3 – C5 range but predominantly butenes) with isobutane in the presence of a strong acid catalyst either sulfuric acid or hydrofluoric acid. The resulting product of the reaction (alkylate) is a mixture of highly branched paraffin molecules (mainly C8’s). Alkylate is often referred to as the optimum blending component for clean gasoline due to its high octane, low vapor pressure, and other clean burning characteristics as well as the fact that it contains no sulfur, aromatics or olefins.

In the sulfuric acid based alkylation process, the acid is continually cycled through the process; but as it cycles, it becomes diluted and contaminated from impurities in the hydrocarbon feeds. Because the concentration of the H2SO4 catalyst is important to the efficiency of the alkylation reaction, when the concentration of H2SO4 decreases to about 88 percent, a portion of the contaminated H2SO4 is withdrawn and replaced with fresh acid. The contaminated, dilute H2SO4 is then regenerated to its original purity and concentration.

The classic refiner approach to regenerating the acid, is to ship the spent acid to another location for regeneration.

With respect to sulfur recovery, refiners normally recover their produced sulfur by processing their sulfur gas in Claus-Tail Gas Units (TGU) that converted the sulfur gases to elemental sulfur. This recovered elemental sulfur is then sent to an acid regeneration facility, in some cases it is the same facility that process a refiners spent sulfuric acid.

Simply put, the classic approach to sulfur management does little to utilize the inherent synergies between the various technologies.
A BETTER ALTERNATIVE

Cleary, there are significant synergies associated with locating a sulfuric acid plant at a refinery. For a refiner fortunate to have in their refinery or having the foresight to expand or install a sulfuric acid alkylation unit in their refinery, installing a sulfuric acid plant that regenerates the spent acid and recovers acid gas as sulfuric acid, can compliment the alkylation unit while increasing a refiners sulfur recovery capacity and thereby avoid capital investment to construct one or more classic claus-tail gas units.

Provided that the two technologies are properly designed and operated to optimize each unit’s capabilities, such a combination can provide a number of benefits to the refinery.

From an environmental compliance perspective, a refiner can reap the benefits of the overall improvement in emissions performance as compared to standalone Claus or Claus/Tail Gas Unit train. As shown in Figure 6, the performance of an enhanced sulfur recovery acid plant can provide emissions that are 6-fold lower than a standard Claus/TGU train and a factor of 3.5 lower than a standard best achievable control technology (BACT) acid plant. An additional, advantage of acid plant-based sulfur recovery is that properly designed sulfuric acid plants have the ability to provide amine and sour water stripper gas processing capability as well as providing on-site regeneration of spent sulfuric acid used in sulfuric acid alkylation units.

From a clean fuels perspective, having an acid plant on-site allows a refiner to custom tailor their alkylation operations by varying the spent acid strength sent to the acid regeneration unit. Optimum alkylate quality can be achieved by maintaining the acid strength in the unit in the range of 92 wt% to 94 wt%. However, for a refinery without an integrated acid unit, the cost of transporting the additional to and from the refinery often offset the benefits realized by increasing the spent acid strength. With an integrated sulfuric acid regeneration unit, increased alkylate quality can be achieved increasing the spent acid strength with a minimal increase in incremental operating cost.
From a sulfur management perspective, the benefits of an on-site acid plant are the reduction of the overall environmental footprint of the source-to-end-consumer supply chain created by the one processing step (refinery SRUs) and subsequent transportation of the sulfur and sulfuric acid it reduces. Acid-plant-based sulfur recovery enables the on-site processing of spent sulfuric acid, reducing the need to transport sulfuric acid to and from regional acid regeneration facilities. Other sulfur management advantages include the ability of the acid plant to provide periodic, back-up acid gas processing. Dual capability of gas and spent acid processing, allows refineries to avoid investment in redundant sulfur recovery units that only process sulfur containing gas streams, when back of other units is needed.

An extension of this scenario is to design the acid plant with sufficient capacity to allow the shut down of a portion or all of a refinery’s existing sulfur recovery units. Dual acid plant trains provide the necessary on-stream time needed to allow total replacement of existing SRU areas with sufficient flexibility in operations to reliably process spent acid and sulfur gases. Utilization of an acid plant in these configurations is an elegant solution since virtually all of the sulfur recovered in the US refinery industry is subsequently burned to produce sulfuric acid in sulfur burning acid plants.

Other benefits include the integration of utility generation and consumption between a refinery and a sulfur acid plant. Depending on its configuration, an acid plant can generate 1.0 to 1.4 pounds of high pressure steam for every pound of acid produced. Most refiners can utilize this steam for their operations. In some cases the amount of steam generated can replace that of existing package boiler further reducing capital investment, operating cost and making significant reductions in CO₂ emissions.

If the refiner is contemplating or even has a regenerative stack scrubbing system such as DuPont-Belco® LABSORB™ Scrubber System, the recovered SO₂ can be processed in an acid plant to produce additional sulfuric acid with minimal increases in capital investment for the acid plant.

These are just a few of the synergies that an integrated alkylation-sulfuric acid can bring to a refiner while meeting the challenges of complying with increasingly stringent environmental regulations, demanding clean fuel requirements, and decreasing crude quality.

**KEYS TO SUCCESS OF AN INTERGRATED ALKYLATION-SULFURIC ACID UNIT**

Approximately a dozen or so refineries utilize aspects of the integrated alkylation-spent acid regeneration (SAR)/sulfur gas recovery (SGR) unit approach to meet their sulfur management, environmental compliance, and clean fuel needs. Many of these integrated facilities operated within the United States or US territories. Some are operated by refineries themselves while others utilize a third party experienced in sulfuric acid production and who is familiar with the acid markets.

The success of these of units varies. However, in most cases the facilities owned and operated by petroleum refineries have limited success. In contrast, the operations that utilize a third party to design, own, and operate their acid facilities operate better with higher on-stream time and reliability.

Presented by Eric Ye at The Sulphur Institute’s tenth biennial, international Sulphur Market Symposium, on April 4-6, 2006 in Beijing, China
The data seems to indicate that in order to operate an integrated facility in a safe, reliable, environmentally sound, and profitable manner a refiner should utilize a third party experienced in sulfuric acid production and who is familiar with the acid markets. However, not all acid manufactures are created equal. Characteristics that a refiner should consider when developing a relationship with a third party are,

- **Expertise and Experience with Sulfuric Acid Technology** – The third party should have extensive experience in not only operating sulfuric acid units, but designing them as well. This ensures that characteristics unique to the specific customer requirements are not only incorporated into the unit design, but are considered in the training of the operating staff.

A company with a track record of innovation in the industry is especially attractive in that cutting edge technology can constantly be incorporated in the unit design and operation.

- **Financially Sound** – This almost goes without saying. Third parties that have limited financial resources are often inclined to “cut corners” in the design of the unit. Furthermore, they often do not properly maintain their units. The net result of this is unreliable operation and some cases interrupted refinery operations.

- **Extensive Knowledge and Experience in Marketing of Acid** – This attribute is characteristic of sulfuric manufactures who are in the business for the long term. In addition, it provides additional flexibility to the acid facility to minimize operating cost and provide additional back-up supplies of sulfuric acid thus ensuring that a refiner's sulfuric acid or sulfur will not be a limiting factor in the refinery operations.

- **Core Values** – The most important characteristics of a third party are their core values. Above all, the third party must encourage and practice a culture of safety, environmental responsibility, and respect for others, characteristics practice by most petroleum refiners in today’s world.

**WHY CHOOSE DUPONT**

DuPont as a company is over 200 hundred years old. DuPont’s involvement in the industry dates back to the first commercial production of sulfuric acid. DuPont Refinery Solutions is a business that has over 100 years of sulfuric acid manufacturing and marketing experience. Sulfuric acid regeneration is a core business for DuPont and the company is looking to grow this business globally. In addition DuPont brings approximately 75 years of experience in alkylation technology development and licensing with the acquisition of STRATCO®, the leading technology provider in sulfuric acid alkylation technology. The recent addition of BELCO®, a company known by the refining industry to provide superior air emission control technologies, applies yet another technology to the suite of solutions that are optimized for each refinery to help them achieve their objectives with a solution that is lower or neutral in cost to the refinery’s next best alternative. Although DuPont has access to a vast array of internal technologies, the evaluation process extends to all commercially proven technologies which can be licensed and integrated with our offering- providing maximum benefits to refinery and community stake holders.

Identifying an acceptable solution requires close collaboration with refinery technical and environmental personnel. But, if a refiner chooses to work with DuPont, the onus
to evaluate the technical capabilities and economics of each alternative solution is no longer a load on the refinery’s technical staff. This allows them to focus on existing hydrocarbon improvement projects. In addition, all permitting and construction activities are managed by DuPont Refinery Solutions.

DuPont currently is successfully operating a commercial application of this integrated approach to sulfur management at our Red Lion Sulfuric Acid Unit located next to the Refinery in Delaware City, DE, USA. Two other integrated alkylation-SAR/SGR units are in the design and construction phase in the United States. A fourth European refinery has signed a letter of intent to install an integrated alkylation-SAR/SGR unit. Details concerning these commercial applications are summarized in Table 4.

**Table 4**

**Commercial Applications**

**Delaware City Refinery – DuPont Red Lion Plant**

- Plant now on stream.
- The DuPont facility receives spent acid and sulfur-bearing streams generated at the refinery regenerate the acid and return it to the refinery for use in the alkylation unit.
- The new plant employs 25 employees at the Red Lion facility.
- Replaced the refinery’s decommissioned sulfuric acid plant.
- Is run by experienced DuPont management and will operate independently of the refinery.
- Reduces total environmental impact compared to the alternative environmental solution for the refinery.
- Reduces sulfur dioxide emissions by 50% from permitted levels at the refinery’s decommissioned sulfuric plant.

**Total Sulfur Solution: Replace Refinery Sulfur Recovery System and Spent Acid Regeneration (2 Projects under Construction)**

- DuPont will Build, Own, Operate and Maintain a dual train acid regeneration unit
- DuPont will regenerate spent acid from existing or new alkylation unit
- DuPont will process all of the high strength sulfur bearing gases from the refinery, replacing existing or required Claus capacity
- Sulfur Gases Can Include: Amine Gas, Tail Gas, SWS Gas, and Stack Scrubber Gases (from a regenerative scrubbing system)
- DuPont will market acid not required by refinery
- Operational availability of new acid regeneration Units can be better than for existing Claus units
- DuPont acid plants have lower Sulfur Dioxide emissions than Claus/TGU systems

Clearly, refiners can and are realizing the significant benefits can be realized by utilizing an integrated alkylation-sulfuric acid regeneration (SAR)/sulfur gas recovery (SGR) unit to meet their sulfur management, environmental, and clean fuel challenges.
CONCLUSION

Operating flexibility at refineries is decreasing as additional constraints are placed on allowable emissions, crudes become more sour, and more stringent refined product specifications are put in place. These dynamics developed over time and have often been addressed as one-off problems within a refinery resulting in sub-optimized solutions. Holistic approaches such as a DuPont owned, operated and maintained acid plant at a refinery provide the dual capability of acid gas processing and spent sulfuric acid regeneration, while allowing a refinery to maximize SRU capability, improve emissions performance and focus capital and manpower on hydrocarbon processing projects. Cost savings of 10% to 30%, relative to investment in classic SRU capacity, can be achieved using the options discussed in this article. Additional benefits can be obtained through the proprietary DuPont STRATCO® integrated acid/alkylation or even BELCO® Regenerative Scrubber facility designs.

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