Chiquita Canyon Landfill

Facility ID 119219

Hydrogen Sulfide and Dimethyl Sulfide Treatment Option Evaluation

Chiquita Canyon Landfill (CCL)

29201 Henry Mayo Dr,

Castaic, CA 91384

SCS ENGINEERS

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4330 Lewis Road, Suite 1
Harrisburg, Pennsylvania 17111
(717) 671-1710

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1.0 INTRODUCTION

Under the modified Stipulated Order for Abatement (SOFA) No. 6177-4, dated June 3, 2026, as agreed to by the South Coast Air Quality Management District (SCAQMD or District) and Chiquita Canyon Landfill (CCL/Site), CCL is required to investigate known and possible pre-combustion sulfur oxides (SO_x) control systems and evaluate whether these systems can be practically applied at the Landfill. Specifically, Condition No. 3(c) of the SOFA requires the following:

> *"Respondent shall investigate and prepare a report on potential solutions to address the potential cause(s) of the vessel fires identified in the report prepared pursuant to Condition 3(b) and/or build upon the Landfill Gas DMS Treatment Study submitted pursuant to Condition 12(g)(i) and updates submitted as required by Condition 8(j) to identify alternative known and possible pre-combustion H_2S or SOx control systems, viability of such system(s), and feasibility of operation of such system(s) at the landfill. The report shall detail the results of the investigation, and, if relevant, H_2S or SOx control systems identified, feasibility of the systems at the landfill, advantages/disadvantages of the control systems, viability and expected H_2S or SOx control efficiency, expected limitations (if any) due to conditions at the landfill, a list of equipment which may be required for installation (e.g. new carbon media vessel(s), etc.), and a proposed timeline for design, procurement, and installation of such system(s). The report shall be submitted to South Coast AQMD [Baitong Chen, Air Quality Engineer, (bchen@aqmd.gov); Nathaniel Dickel, Senior Air Quality Engineer, (ndickel@aqmd.gov), and Christina Ojeda, Air Quality Inspector, (cojeda@aqmd.gov)] by August 28, 2026."*

2.0 BACKGROUND

2.1 EXISTING SULFUR TREATMENT SYSTEM

In 2018, CCL installed a centralized LFG Treatment System (LFGTS) to remove H_2S from LFG before combustion in the Site's flares. Permitted under Permit No. G55163, the LFGTS includes four carbon-media treatment vessels, LFG collection and conveyance piping, a blower flare station, utilities, electrical systems, controls, monitoring equipment, access roads, and condensate-management infrastructure. The system was designed to reduce sulfur concentrations and support compliance with sulfur-related permit requirements and SOx emission limits. Refer to Appendix A for the system design drawings

2.2 2026 CARBON MEDIA TANK FAILURE

On January 16, 2026, elevated LFG temperatures and a localized hot spot were identified at H_2S Treatment Tank No. 2, followed by visible flames near the bottom of the vessel. Site personnel cooled and contained the affected area, extinguished the flames, and secured the Site. Tank No. 2 was removed from service, LFG flow was rerouted through Tanks Nos. 1 and 4, and treatment media was not reinstalled pending further investigation and implementation of appropriate safeguards.

CCL and the treatment-system manufacturer initially evaluated potential causes but could not identify a definitive failure mechanism because damage to internal components limited the investigation. Following the June 2026 SCAQMD hearing and modification of the SOFA, SCS expanded the investigation on CCL's behalf to conduct a comprehensive root-cause evaluation consistent with Condition 3(b). SCS submitted an initial Condition 3(b) report on July 17, 2026, containing preliminary findings because the investigation was ongoing.

Subsequent third-party forensic findings identified prolonged exposure to temperatures exceeding the fiberglass-reinforced epoxy vessel's design limits as the most probable cause of failure, with rupture occurring at a previously repaired section. Visual observations and laboratory testing documented extensive thermal degradation of internal structural components but found no evidence that manufacturing defects, chemical attack, or material incompatibility caused the failure.

Evidence of long-term elevated-temperature exposure was also observed elsewhere in the H_2S treatment tank farm, and repairs to affected vessels may not provide the performance or durability of the original construction. These findings, together with the existing system configuration described in Section 2.1.1, establish the basis for evaluating replacement or alternative pre-combustion sulfur-control systems that can operate safely and feasibly at the Site, as described in Section 2.1.3.

2.3 PURPOSE OF THIS EVALUATION

The purpose of this evaluation is to investigate potential solutions that address the potential causes of the vessel fires identified pursuant to Condition 3(b) and to build upon the previous LFG di-methyl sulfide (DMS) Treatment Study, prepared by SCS, April 30, 2024, and subsequent updates. The evaluation identifies known and potential alternative pre-combustion H_2S and SOx control systems and assesses their viability and feasibility for operation at CCL. For each relevant alternative, the evaluation considers anticipated control efficiency, advantages and disadvantages, Site-specific operating limitations, required equipment, and the anticipated timeline for design, procurement, and installation.

3.0 BASIS AND SCOPE OF EVALUATION

This report presents a screening-level engineering evaluation based on available CCL operating data, prior testing, and readily available information supplied by technology vendors. The evaluation identifies alternatives that may warrant further development but does not establish that any particular technology or configuration is presently practical, reliably operable, or economically viable for full-scale application at CCL. This report is not a final process design, equipment specification, performance guarantee, or procurement recommendation. Final equipment sizing, safety controls, permitting requirements, performance guarantees, and capital and operating costs would be developed through subsequent engineering and vendor evaluation.

3.1 PREVIOUS INVESTIGATIONS

3.1.1 Previous Investigations and Regulatory Drivers

Since early 2024, CCL has evaluated sulfur treatment and preventative measures through the DMS treatment study completed by SCS on behalf of the Reaction Committee under SOFA Condition 12(g)(i). The study included review of available treatment technologies, consultation with industry experts and vendor outreach, pilot testing efforts, and reviews of published research to assess both existing and emerging approaches for DMS control. The technologies considered in the prior study were reconsidered for evaluation in light of the current site conditions, and limited availability of proven full-scale DMS treatment systems.

CCL has continued to evaluate sulfur treatment alternatives through additional vendor engagement, bench-scale and field testing of oxidation and adsorption technologies, and a forensic investigation of the 2026 sulfur treatment vessel thermal event. Collectively, these efforts have improved the understanding of site-specific sulfur treatment challenges, identified technical limitations associated with conventional sulfur treatment systems, and informed the evaluation of replacement and alternative pre-combustion sulfur treatment systems presented in this report.

3.1.2 Historical Treatment Findings

The April 30, 2024, DMS treatment study evaluated media and treatment technologies that could inform replacement of the existing H_2S treatment vessels or development of a different pre-combustion sulfur-control system. For the current evaluation, those previously considered technologies were revisited in light of the 2026 vessel thermal event, current Site conditions, and the need for a safe and feasible replacement system. Alternatives that could use a conventional vessel-based configuration, including changes to treatment media or vessel materials, are evaluated alongside technologies that would require an entirely new treatment train. The relevant prior findings are incorporated into the alternatives analysis in Section 3.2 rather than repeated in detail here.

3.1.2.1 Copper-Impregnated Activated Carbon

A pilot study was conducted utilizing copper-impregnated activated carbon in combination with conventional activated carbon.

- Initial testing reduced DMS from 109 parts per million by volume (ppmv) to 0.9 ppmv after one (1) day.
- Performance rapidly declined within several days.

- Subsequent testing confirmed the technology was ineffective for consistent, long-term DMS removal despite remaining effective for H_2S removal.

This technology was ultimately eliminated from further consideration.

3.1.2.2 Sodium Hypochlorite Oxidation

Field testing using sodium hypochlorite demonstrated:

- Initial DMS reductions approached 88 percent (%).
- Treatment efficiency deteriorated to near-zero within one (1) week.

The technology was deemed unsuitable for long-term treatment due to rapid oxidant consumption and declining effectiveness.

3.1.2.3 Streamline TALON® / Hydrogen Peroxide

Research identified reduction-oxidation (redox) treatment using TALON catalyst and hydrogen peroxide as a potentially viable treatment approach. The process converts sulfur compounds into elemental sulfur that can be removed from the treatment stream.

CCL retained Streamline Innovations to bring a pilot unit on site and tested it at a wellhead for TRS reduction. The pilot was not successful due to the chemical reaction pathway; it was later suggested that adding a hydrogen peroxide stage would complete the regenerative chemical reaction pathway where it had failed previously. CCL believed this warranted bench-scale testing, but was not granted the ability to test it by SCAQMD. The process converts sulfur compounds into elemental sulfur that can be removed from the treatment stream

3.1.2.4 Clean Harbors Potassium Permanganate

Clean Harbors proposed a permanganate oxidation process capable of converting sulfur compounds into elemental sulfur. Due to promising theoretical performance, CCL notified SCAQMD and initiated bench-scale testing in 2024.

Although the testing occasionally achieved meaningful DMS reductions, variations in LFG flow and competing contaminant loading, including volatile organic compounds (VOCs), resulted in inconsistent and incomplete chemical reactions. Consequently, the composition of the outlet gas varied, and significant DMS reduction was achieved only intermittently. In addition, sulfur compounds and VOCs not detected in the inlet gas were identified in some outlet samples.

3.2 SITE-SPECIFIC EVALUATION CRITERIA AND DESIGN BASIS

3.2.1 Existing Infrastructure

As described in Section 2, the existing LFGTS includes four (4) carbon media vessels for H_2S removal, associated LFG conveyance, blower flare station, utilities, controls, instrumentation, electrical systems, and condensate management infrastructure. For purposes of this evaluation, this infrastructure was considered to determine whether each alternative could replace or integrate with the existing sulfur treatment system, use available utilities and controls, and maintain connection to the downstream blower flare station. The extent to which an alternative can use the existing

treatment area and supporting infrastructure affects its constructability, implementation schedule, and need for new equipment, as discussed in the following sections.

3.2.2 Physical/Space Limitations

The available space for construction of a new treatment facility was considered as part of the evaluation. Several potential installation locations were identified, including the existing treatment tank area, the decommissioned Ameresco (onsite gas-to-energy vendor) facility, and the partially excavated area northeast of the current treatment facilities.

The existing H_2S treatment system occupies an area of approximately 93 feet by 36 feet (approximately 3,350 square feet), exclusive of additional access and staging areas required for maintenance activities. Including operational access requirements, the treatment area is estimated to occupy approximately 4,000 to 5,000 square feet. Refer to Appendix A for design drawings from this construction event.

The decommissioned Ameresco facility occupies an area of approximately 26,000 square feet (0.62 acres) based on aerial measurements. The area corresponds to an approximate footprint envelope of 370 feet by 70 feet and provides substantially more available space than the existing H_2S treatment area. However, this area is unavailable to CCL for any purpose due to contractual conditions with Ameresco.

Future site development plans, including the potential installation of employee trailers within currently available areas, were also considered. Treatment technologies with large equipment footprints, significant tank requirements, or extensive ancillary systems may be limited by the space available for construction.

Based on currently available information, the existing treatment area and nearby vacant areas represent the primary locations considered for implementation of replacement or alternative sulfur treatment systems.

3.2.3 Site Logistics and Media Management Considerations

In addition to treatment system footprint requirements, implementation of any sulfur treatment technology must consider the operational impacts associated with equipment installation, media deliveries, media removal, temporary storage, and routine maintenance activities. Several of the technologies evaluated rely on periodic replacement of large quantities of treatment media, requiring truck access, equipment staging areas, and temporary storage locations for both fresh and potentially spent media. Treatment systems requiring frequent media replacement may increase traffic within the treatment area and could create operational conflicts with ongoing landfill activities, maintenance operations, and future site development plans. Technologies with high projected media consumption rates may also require additional logistical planning to accommodate media transportation, unloading, storage, and disposal activities.

3.2.4 Treatment Performance Criteria

The primary objective of this evaluation is to identify a replacement or alternative pre-combustion sulfur treatment system that reduces sulfur emissions while addressing concerns around vessel thermal events, and can be operated safely and feasibly at the Site. Existing sulfur-related permit requirements and treatment targets were considered as performance benchmarks, but an

alternative was not excluded solely because it may not independently reduce total sulfur concentrations to permitted levels.

The current operating requirements include a daily average total sulfur concentration limit of 80 ppmv and a monthly average total sulfur concentration limit of 60 ppmv at the treatment system outlet. Accordingly, the evaluation considers each alternative's expected reduction of H_2S, DMS, and total sulfur, including systems that may provide meaningful incremental sulfur reduction or safely replace the existing H_2S treatment function even if additional controls would be required to achieve full compliance.

Permit No. G55163 authorizes the centralized sulfur treatment system to include up to six 12-foot-diameter treatment vessels, although four vessels were installed in 2018. This permitted configuration, together with the potential need for permit modifications for different equipment or operating conditions, was considered when evaluating the constructability and implementation of each alternative.

3.2.5 LFG Composition and Laboratory Sample Results

Available laboratory data and field monitoring results were reviewed to develop representative design conditions for the evaluation. In addition to elevated concentrations of DMS, H_2S, and other reduced sulfur compounds associated with the ongoing landfill reaction event, analytical results collected from the inlet of flare FL-2009 indicate the presence of several volatile organic compounds (VOCs) that may influence treatment performance. The most significant compounds identified were acetone at 83.9 ppmv and 2-butanone at 37.8 ppmv. Smaller concentrations of other VOCs were also detected. Refer to Appendix B for full results from the laboratory gas analysis.

These compounds are particularly important when evaluating adsorption-based treatment technologies because they may compete with DMS for available treatment capacity within the media bed. As VOC concentrations increase, a portion of the media capacity is consumed by these compounds rather than by DMS removal, which can reduce media life and increase the frequency of media replacement. VOCs may also affect certain H_2S adsorption media, although the extent of the effect depends on the media formulation and operating conditions.

For this reason, the evaluation considered both sulfur compound concentrations and the presence of competing VOCs when assessing the expected performance, operating requirements, and long-term costs of each treatment alternative.

3.2.6 Current and Projected LFG Flow Rates

Treatment alternatives were evaluated using current LFG flow conditions as well as projected future operating conditions. Current LFG extraction rates are approximately 18,000 standard cubic feet per minute (scfm), with future flows expected to approach 25,000 scfm. This operating range was used to evaluate equipment sizing, treatment capacity, operating costs, and future expansion requirements. For media-based alternatives, feasibility also depends on the expected media service life and the frequency and duration of changeouts. Alternatives requiring media replacement so frequently that the system cannot sustain meaningful treatment between changeouts, or cannot maintain adequate treatment capacity during changeout activities, may not be operationally feasible at the Site.

3.2.7 Treatment System Design Parameters

The sulfur treatment alternatives were evaluated using the Site-specific criteria described in Sections 3.2.1 through 3.2.6, including compatibility with existing infrastructure, available space, media-management requirements, treatment objectives, LFG composition, and current and projected flow rates. Together, these criteria define the operating conditions and practical constraints applicable to replacement and alternative sulfur treatment systems at the Site.

Each alternative was evaluated for its ability to be safely and reliably implemented; provide meaningful H_2S, DMS, or total-sulfur reduction; accommodate expected operating conditions; and maintain practical treatment capacity between maintenance or media-changeout events. These parameters form the common design basis for the comparative evaluation presented in Section 4.

Table 1. Notable VOC compounds TO-15 Analysis Results FL-2009 – April 4th, 2026

Compound	Concentration (ppm)
Acetone	83.5
2-Butanone	37.8
Tetrahydrofuran	32.4
Isopropyl Alcohol	28.0
Benzene	19.0

Refer to Appendix B for full results from the TO-15 Analysis at the FL-2009 inlet.

Collectively, these Site-specific conditions, operating constraints, treatment objectives, and design parameters form the basis for evaluating and comparing the sulfur treatment alternatives presented in Section 4.

4.0 SULFUR TREATMENT EVALUATION

This evaluation relies primarily on information, performance projections, and technical representations provided by the vendors. Unless otherwise stated, vendor-reported treatment efficiencies, media performance, service life, costs, or other performance claims have not been verified. If an alternative is advanced, applicable performance requirements and guarantees would be established with the selected vendor and evaluated during subsequent design, construction, startup, and operation.

4.1 EVALUATION APPROACH AND SCREENING CRITERIA

To initiate the evaluation, SCS distributed a preliminary information request to multiple treatment vendors describing a LFG stream with anticipated flow rates of 15,000 to 25,000 scfm, gas composition of approximately 30% methane, 22% carbon dioxide, 3% oxygen, and 45% nitrogen, H_2S concentrations ranging from 150 to 200 ppmv, and DMS concentrations ranging from 200 to 1,000 ppmv. These LFG criteria are highlighted in Table 2 below. Vendors were asked to provide information regarding available treatment technologies capable of addressing the reported H_2S and DMS concentrations, identify LFG constituents that could impact treatment performance, and discuss anticipated operating requirements and treatment limitations.

As vendors responded and discussions progressed, SCS provided additional site-specific information to support the evaluation, including TO-15 analytical results collected on April 2nd, 2026 from the FL-2009 inlet and other LFG characterization data. The additional information allowed vendors to better assess the effects of VOCs, moisture, oxygen concentration, and other site-specific operating conditions on the expected performance of their proposed treatment technologies. Vendors were also supplied the current operating requirements of a daily average total sulfur concentration limit of 80 ppmv and a monthly average total sulfur concentration limit of 60 ppmv at the treatment system outlet, as information.

Table 2. Vendor Request Design Criteria

Application	LFG
Operating Conditions:	
Temperature	~90°F – 130°F
Pressure	-60 psig
Flow Rate	15,000 SCFM – 25,000 SCFM
R.H.	~80%
Gas Composition:	
N2	45%
CH4	30%
O2	3%
CO2	22%
H_2S	150ppm – 200ppm
DMS	200ppm – 1000ppm

Application	LFG
Treatment Targets:	
Daily Sulfur Limit	80 ppmv
Monthly Sulfur Limit	60 ppmv

4.2 TREATMENT ALTERNATIVES EVALUATION

In addition to evaluating new treatment technologies capable of addressing both H_2S and DMS, an alternative consisting of replacement of the existing H_2S treatment infrastructure utilizing NORIT's BG-1 activated carbon media was also considered. This alternative would focus on installation of new treatment vessels, replacement piping, controls, and enhanced monitoring systems while maintaining a conventional H_2S adsorption-based treatment approach.

Based on vendor responses, four (4) technologies were identified as warranting further technical evaluation: NORIT Activated Carbon, UNICAT Catalyst Technologies, Theia, LLC, and Axens Group. Each of these vendors indicated potential capability to address both H_2S and DMS and subsequently provided technical information to support a more detailed review of treatment performance, operating requirements, implementation considerations, and potential applicability at CCL.

4.2.1 Replacement of Existing H_2S Treatment System

Feasibility Evaluation

Upgrading the existing H_2S treatment system utilizing NORIT's BG-1 media represents a potential alternative that would maintain a conventional sulfur treatment approach while replacing aging infrastructure and incorporating enhanced monitoring capabilities. This alternative would consist of replacement treatment vessels, associated piping improvements, controls, remote monitoring systems, and BG-1 activated carbon for H_2S removal.

Based on discussions with NORIT, a dedicated H_2S treatment system utilizing larger treatment vessels could provide media replacement intervals exceeding one year while remaining within a relatively conventional adsorption-based treatment framework. Since detailed engineering has not been completed, timeline, cost, utility, and installation information are based on engineering assumptions rather than vendor-provided data.

It is assumed that implementation could be accomplished within or adjacent to the existing treatment area and would require substantially less new process infrastructure than the DMS treatment alternatives evaluated in this report. Utility requirements would be expected to remain generally consistent with conventional sulfur treatment operations, with the addition of monitoring and communications equipment.

Maintenance activities would primarily consist of sulfur monitoring, vessel inspection, and periodic BG-1 media replacement. Downtime requirements cannot be fully evaluated but are assumed to be minimal due to the use of a lead-lag vessel arrangement, which would allow one treatment vessel to remain in service while maintenance activities are performed on the other.

During follow-up discussions, NORIT evaluated a conceptual H_2S treatment configuration consisting of two 26-foot inside diameter (I.D.) treatment vessels operated in a lead-lag arrangement. NORIT indicated that vessels of this size would provide approximately 12,000 cubic feet of media volume

per vessel and could potentially treat the projected landfill gas flow rates of up to 25,000 scfm using a single H_2S treatment train. Based on NORIT's evaluation, the larger-vessel configuration could provide longer H_2S media service intervals while simultaneously allowing the remaining four treatment vessels to be dedicated to downstream DMS treatment. SCS has not independently verified this projected media life, and actual performance would depend on site-specific sulfur loading, operating conditions, gas composition, and final vessel design.

Waste generation would primarily consist of spent BG-1 media requiring periodic removal and disposal. Safety considerations would generally be consistent with conventional activated-carbon sulfur treatment systems and associated media handling activities. However, the viability of this alternative is limited by third-party forensic findings, which identified prolonged exposure to temperatures exceeding the fiberglass-reinforced epoxy vessel's design limits as the most probable cause of failure. The rupture occurred at a previously repaired section of the vessel. Based on these findings, replacement tanks and a more robust monitoring system are required for reliable operation of this system.

4.2.2 NORIT H_2S and DMS Treatment System

Feasibility Evaluation

NORIT's proposed treatment would consist of H_2S treatment, gas dehydration, condensate management, gas reheating, VOC removal, and downstream RB-4 activated carbon for DMS treatment. NORIT provided media delivery lead times of approximately one to two months for BG-1 media and approximately six months for RB-4 media; however, a complete design, procurement, installation, and startup schedule was not provided.

Based on vendor information, the proposed H_2S treatment train would require approximately 3,000 to 4,500 square feet of footprint. Additional space would be required for dehydration, VOC treatment, and DMS treatment equipment. It is assumed that the total installed footprint would be substantially larger than the H_2S treatment footprint alone. Utility requirements would include electrical service for chillers, reheating equipment, instrumentation, controls, and the proposed VOC treatment system, although vendor-specific electrical demands were not provided.

Maintenance activities would require periodic media replacement, condensate management, and servicing of dehydration and VOC treatment equipment. Downtime estimates were not provided by the vendor; however, it is assumed that downtime could be minimized through appropriate lead-lag vessel configurations and planned media replacement schedules. Based on Norit's conceptual design and subsequent discussions, H_2S media replacement activities would occur on a longer interval, while RB-4 DMS media replacement activities could occur approximately every 17 days under the idealized operating scenario presented by the vendor. See Appendix C for more details on this operating scenario**.**

Waste generation would consist primarily of spent BG-1 media, spent RB-4 media, and condensate generated by the dehydration process. Based on vendor-provided RB-4 consumption estimates, annually spent RB-4 generation is estimated by SCS to be approximately 3,231 tons per year. Annual spent BG-1 quantities were not provided by the vendor; however, based on the conceptual H_2S treatment configuration and projected media life exceeding one year, SCS estimates annual BG-1 disposal requirements may range from approximately 120 to 360 tons per year.

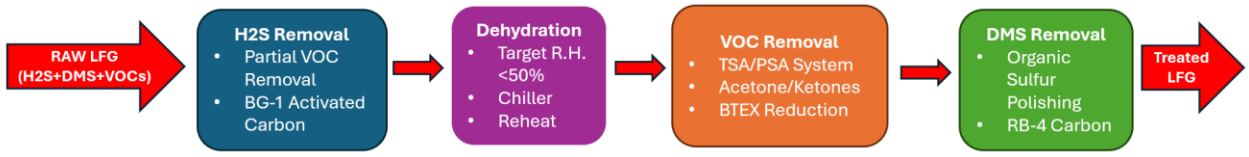
Safety considerations include operation of chilled and reheated gas systems, condensate handling, and sulfur-bearing media replacement activities. Although a complete capital cost estimate was not provided, media replacement costs are expected to be significant relative to the other evaluated alternatives due to the projected annual RB-4 media consumption and additional infrastructure requirements.

Process

NORIT proposes a staged adsorption process designed to treat H_2S and DMS independently using media selected for each contaminant. H_2S removal would be accomplished using BG-1 activated carbon upstream of the DMS removal process. During follow-up discussions, NORIT clarified that DMS behaves more similarly to ketones, acetones, and other oxygenated VOCs than traditional sulfur compounds and is significantly impacted by VOC competition within the carbon bed.

To maximize DMS adsorption capacity, NORIT's preferred treatment approach includes H_2S removal, dehydration, reheating, bulk VOC removal through a regenerative adsorption process Temperature Swing Adsorption / Pressure Swing Adsorption (TSA/PSA), and downstream RB-4 activated carbon for DMS polishing. NORIT indicated that moisture control and VOC reduction are the primary factors affecting DMS media performance and that oxygen concentration is not a significant factor in RB-4 operation. NORIT clarified that the proposed process utilizes separate operating conditions for H_2S and DMS treatment. BG-1 H_2S removal is performed under relatively high moisture conditions (60-100% relative humidity [RH]), while downstream RB-4 DMS treatment requires LFG conditioning to less than approximately 50% RH through chilling, condensate removal, and reheating prior to entering the DMS treatment vessels.

Figure 1. NORIT Proposed Process Diagram



Consumables

The primary consumables associated with the NORIT process are BG-1 activated carbon for H_2S removal and RB-4 activated carbon for DMS removal. Electricity would also be required for dehydration, reheating, VOC removal, instrumentation, and control systems. NORIT identified acetone, ketones, and benzene, toluene, ethylbenzene, and xylene (BTEX) compounds as the principal VOCs competing for adsorption capacity within the DMS treatment beds. During follow-up discussions, NORIT provided preliminary RB-4 pricing of $4.85 per pound for the anticipated project volume and indicated that media inventory would be stocked and managed from its Marshall, Texas facility.

NORIT did not provide sufficient information to estimate electrical demand, annual operating cost, staffing requirements, or the quantity and classification of condensate and spent media. This data would be required before the technology could be fully evaluated or selected for implementation.

Waste Products

The process is expected to generate spent BG-1 and RB-4 media requiring periodic removal and disposal. Sulfur compounds, DMS, H_2S, and competing VOCs are adsorbed onto the media and ultimately removed from service when adsorption capacity is exhausted. NORIT noted that disposal requirements may vary depending on the final contaminant loading of the media and that hazardous waste characterization may be required prior to disposal, particularly where elevated concentrations of benzene or other regulated compounds are present. In addition to spent BG-1 and RB-4 media, the dehydration system is expected to generate condensate requiring collection and liquids management. NORIT noted that a portion of water-soluble VOCs may also be removed during the dehydration process and report to the condensate stream. For comparison, current operations require approximately two days to complete replacement of media within a single 25-ton treatment vessel. The frequency of future media changeouts may have an impact on maintenance requirements, operational logistics, equipment availability, and overall site activities.

Operation and Maintenance (O&M) Requirements

Operation and maintenance activities are expected to include monitoring sulfur treatment performance, operation of the dehydration and VOC removal systems, management of condensate generation, and periodic media replacement. NORIT emphasized that moisture control is one of the most important operating parameters because elevated humidity can significantly reduce DMS treatment effectiveness. During follow-up discussions, NORIT identified a commercially available Camlin monitoring system capable of providing approximately hourly DMS measurements at low ppm concentrations and indicated that this technology has been used by other customers to optimize media replacement timing.

Lead Times

NORIT indicated an estimated lead time of approximately one to two months for initial BG-1 delivery and approximately six months for initial RB-4 delivery. Once inventory is established, NORIT estimates changeout media could typically be supplied within approximately two to three weeks. BG-1 media would ship from Texarkana, Texas, while RB-4 media would ship from Marshall, Texas. These estimates address media procurement only and do not represent the full implementation schedule.

The proposed treatment train would require design and construction of a substantially new system, including dedicated H_2S and DMS treatment vessels, dehydration and condensate-management equipment, gas reheating, regenerative VOC removal, monitoring instrumentation, controls, utilities, interconnecting piping, and Site civil improvements. Before procurement, additional vendor testing and design development would be needed to confirm treatment performance, media life, vessel sizing, equipment layout, utility demand, safety controls, and waste-management requirements under Site-specific conditions.

The overall schedule would also need to account for pilot or bench-scale testing, permitting, detailed engineering, equipment fabrication, Site preparation, utility upgrades, construction, system integration, commissioning, performance testing, and operator training. Long-lead equipment may include the treatment vessels, dehydration and VOC-removal systems, controls, and electrical components in addition to the RB-4 media. Because NORIT did not provide durations for these activities, a complete implementation schedule cannot yet be established and would require further design development and coordination with the vendor and permitting agencies

Viability

NORIT indicated that DMS treatment is technically feasible using RB-4 activated carbon; however, treatment performance and media life are highly dependent on upstream moisture control and VOC reduction. The vendor concluded that DMS removal can be achieved provided adequate gas conditioning is incorporated into the treatment train.

Equipment List

- BG-1 H_2S treatment vessels
- RB-4 DMS treatment vessels
- Dehydration/chiller system
- Gas reheat system
- Regenerative VOC removal system (TSA/PSA type)
- DMS monitoring instrumentation
- Condensate collection and management system

The proposed NORIT treatment train would require a new system rather than a direct connection to or reuse of the existing sulfur treatment vessels. Although the new system would integrate with the existing upstream and downstream LFG conveyance infrastructure, implementation would require substantial engineering to establish the final process configuration, vessel sizing, equipment layout, utility requirements, safety controls, and tie-in design. Significant procurement and construction efforts would also be required for the treatment vessels, gas-conditioning and VOC-removal equipment, controls, electrical systems, interconnecting piping, civil improvements, permitting, startup, and commissioning.

Information Not Provided

Although NORIT provided substantial information regarding process configuration, treatment media, lead times, and conceptual operating requirements, certain information requested during this evaluation was not provided. Specifically, NORIT did not provide detailed electrical demand estimates, dehydration system consumable requirements, condensate generation rates, waste characterization or disposal requirements for spent media, labor and staffing requirements, annual maintenance costs, or a comprehensive annual operating cost estimate. As a result, portions of the operating cost, utility demand, waste management, and operations and maintenance evaluations were based on assumptions and available vendor information.

See Appendix C for additional documentation supplied by NORIT Activated Carbon.

4.2.3 UNICAT Treatment System

Feasibility Evaluation

UNICAT's proposed treatment approach appears technically feasible and utilizes dedicated treatment stages for H_2S removal, VOC removal, and DMS treatment. The vendor provided estimated lead times ranging from approximately 13 to 25 weeks for initial media deliveries and approximately 4 to 6 weeks for replacement media under a supply agreement; however, a complete implementation schedule was not provided.

The proposed system consists of six 20-ft I.D, treatment vessels and would require sufficient space for media handling and maintenance access. Because a final site layout was not provided, overall footprint requirements are based on the proposed vessel diameters. Utility requirements are expected to be limited primarily to monitoring systems, condensate management, and potential water injection to maintain saturated operating conditions; however, electrical demand was not quantified by the vendor.

Maintenance activities would primarily consist of sulfur monitoring, VOC monitoring, condensate management, and periodic replacement of treatment media. Downtime estimates were not provided. It is assumed that the multiple-vessel configuration would allow staggered media replacement activities and minimize interruptions to treatment operations.

Based on vendor-provided media life estimates, SCS assumes SR-101D replacement would occur approximately once every 40 months, while HRU-CSP and TSR-12SF media replacement would occur approximately every 1 to 2 months. It is assumed that these replacement activities could be performed on an individual-vessel basis without requiring a complete treatment system shutdown.

Waste generation would consist primarily of spent SR-101D, HRU-CSP, and TSR-12SF media. Based on vendor-provided media service life estimates and the proposed treatment configuration, SCS estimates annual TSR-12SF disposal quantities may range from approximately 1,000 to 1,600 tons per year. For reference, current site operation generated 650 tons per year The vendor projected an SR-101D media life of approximately 40 months, indicating comparatively low annual disposal quantities for the H_2S treatment media. Annual HRU-CSP disposal quantities were not explicitly provided; therefore, the total waste generation rate is based partially on engineering assumptions and would likely vary depending on actual VOC loading and media replacement frequency.

Safety considerations include sulfur-bearing media handling, operation under saturated gas conditions, and maintenance of iron oxide treatment systems. While a complete installed-system cost was not provided, initial media inventory costs and projected replacement frequencies indicate that long-term operating costs will be strongly influenced by media replacement requirements.

Process

UNICAT recommends a staged adsorption process utilizing dedicated treatment media for H_2S, VOCs, and DMS. The proposed configuration consists of an upstream SR-101D iron oxide adsorbent for H_2S removal, followed by UNICARBON HRU-CSP activated carbon for VOC removal, and downstream TSR-12SF bi-metal impregnated activated carbon for DMS polishing.

UNICAT indicated that oxygenated VOCs can significantly reduce DMS media life through competitive adsorption and therefore recommends a dedicated VOC removal stage upstream of the TSR-12SF media. The vendor predicts outlet H_2S concentrations below 2 ppmv and outlet DMS concentrations below 60 ppmv, allowing the treated gas stream to meet the target sulfur specification of less than 60 ppmv total sulfur. An optional 25% bypass configuration may also be utilized to reduce media consumption while maintaining compliance with outlet sulfur requirements.

Figure 2. Unicat Proposed Process Diagram



Consumables

The primary consumables associated with the UNICAT process include SR-101D iron oxide media for H_2S removal, UNICARBON HRU-CSP activated carbon for VOC removal, and TSR-12SF media for DMS removal. Based on the technical proposal, SR-101D media is projected to have an approximate service life of 40 months, while both the HRU-CSP and TSR-12SF media are projected to require replacement every one to two months under the design conditions evaluated. UNICAT also recommends Densimax ceramic support media for vessel grading and flow distribution. Based on the commercial proposal, the initial media inventory includes approximately 22,050 ft^3 of SR-101D media, 10,045 ft^3 of HRU-CSP media, and 11,998 ft^3 of TSR-12SF media distributed across six proposed treatment vessels.

Waste Products

The primary waste streams generated by the UNICAT process consist of spent iron oxide media, spent VOC-removal activated carbon, and spent DMS-removal media. Sulfur compounds, DMS, and VOCs are retained within the sorbents and removed from service during replacement events. UNICAT also identified condensate management as a design consideration for the H_2S removal vessel due to operation under saturated gas conditions.

O&M Requirements

O&M activities are expected to include sulfur monitoring, TOC monitoring, condensate management, periodic media replacement, and routine vessel inspections. UNICAT recommends monitoring sulfur concentrations downstream of each treatment train and periodically monitoring TOC speciation to optimize VOC media replacement frequency. The vendor noted that the VOC-removal layer will experience chromatographic breakthrough and therefore may require periodic adjustment of replacement schedules based on actual field performance. Oxygen must remain present within the H_2S treatment vessel during operation to prevent excessive heat generation associated with iron sulfide oxidation.

Lead Times

UNICAT indicated initial media lead times of approximately 20 weeks for SR-101D, 13 weeks for HRU-CSP, and 25 weeks for TSR-12SF. Initial system media loading would therefore require approximately 25 weeks following purchase-order issuance. Subsequent media deliveries may be reduced to approximately four to six weeks if a supply agreement and inventory-stocking program are established. These estimates address media procurement only and do not represent the full implementation schedule.

The proposed treatment train would require a new six-vessel system with dedicated H_2S, VOC, and DMS treatment stages rather than reuse of the existing vessels. Implementation would require further vendor coordination and detailed engineering to confirm treatment performance, media life,

vessel sizing, equipment layout, utility requirements, foundations, safety controls, monitoring, condensate management, media-handling provisions, and connections to the existing upstream and downstream LFG infrastructure.

The overall schedule would also need to account for permitting, procurement and fabrication of the vessels and ancillary equipment, Site preparation, civil and electrical work, construction, media delivery and loading, system integration, commissioning, performance testing, and operator training. Long-lead items may include the treatment vessels, monitoring and control equipment, and initial TSR-12SF media. Because UNICAT did not provide durations for these activities, a complete design-through-startup schedule cannot yet be established and would require additional engineering development and coordination with the vendor and permitting agencies.

Viability

UNICAT stated that the proposed treatment train is capable of reducing outlet H_2S concentrations below 2 ppmv and total sulfur concentrations below 60 ppmv under the evaluated operating conditions. The vendor considers the process technically viable provided VOC and sulfur loading remain within the design basis used during proposal development

Equipment List

- SR-101D H_2S Vessels
- HRU-CSP VOC removal vessels
- TSR-12SF DMS treatment vessels
- Densimax ceramic support media
- Sulfur monitoring equipment
- TOC/VOC monitoring equipment
- Condensate management equipment
- DMS Monitoring equipment
- Potential water injection system (if required to maintain saturation)

The UNICAT alternative would require substantial new treatment and support equipment rather than reuse of the existing sulfur treatment vessels. Accordingly, significant engineering would be required to finalize the process configuration, vessel sizing, equipment layout, foundations, utilities, controls, monitoring, condensate management, media-handling systems, and connections to the existing LFG infrastructure. Procurement and fabrication of the vessels, ancillary equipment, and initial media inventory would also require considerable lead time; therefore, construction, commissioning, and operation could not begin until the necessary design, permitting, and procurement activities are substantially complete.

Information Not Provided

UNICAT provided process descriptions, media sizing information, projected media service lives, and media lead times; however, several details requested as part of this evaluation were not supplied. Specifically, the vendor did not provide disposal requirements or waste classification guidance for spent treatment media, detailed labor or staffing requirements, maintenance frequencies, annual maintenance costs, or a complete installed-system cost estimate. Consequently, portions of the waste management and long-term operations and maintenance evaluations required assumptions based on the information made available by the vendor.

See Appendix D for additional documentation supplied by UNICAT Catalyst Technologies.

4.2.4 Theia Biological Treatment System

Feasibility Evaluation

Theia's proposed treatment would consist of a multi-stage biological treatment system focused primarily on DMS removal while also addressing H_2S. The vendor estimated a fabrication and delivery schedule of approximately 20 to 22 weeks and provided an estimated treatment footprint of approximately 50 feet by 120 feet. Electrical demand was estimated at approximately 100 to 150 kVA and would support pumps, blowers, oxygenation equipment, instrumentation, and sludge-handling systems. Additional utility requirements include process-water management and biological treatment support systems.

Maintenance activities would include inspection and maintenance of biological reactors, pumps, oxygenation systems, biofilters, sludge dewatering equipment, and Icarus-media delivery systems. The vendor did not provide specific downtime estimates; however, it is assumed that most maintenance activities could be performed while maintaining continuous system operation due to the distributed nature of the treatment process. Unlike the adsorption-based alternatives, Theia does not rely on periodic replacement of fixed treatment beds. Based on vendor-provided information, the Icarus media would be continuously replenished during operation and would not require dedicated system outages for media replacement.

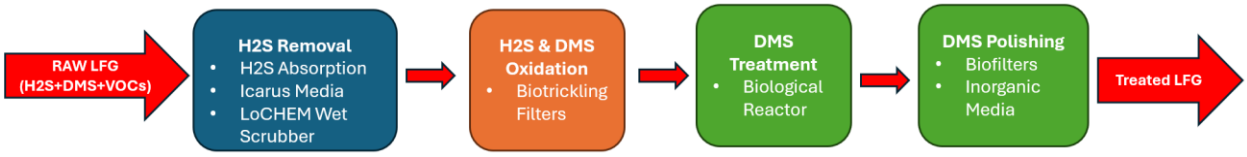
Waste generation would include dewatered sludge and spent Icarus media requiring routine removal and disposal. Based on vendor-provided information, sludge generation is estimated at approximately 2 to 3 tons per day, corresponding to approximately 730 to 1,095 tons per year. Icarus media consumption is estimated at approximately 1.0 to 1.5 tons per day, corresponding to approximately 365 to 548 tons per year.

Safety considerations include biological process management, sludge handling, process-water systems, and confined-space entry requirements associated with treatment equipment. Theia provided a cost estimate among the evaluated alternatives; however, certain long-term operating costs, including sludge disposal and ongoing equipment maintenance, would require additional refinement during final design.

Process

The proposed process includes an initial LoCHEM wet scrubbing system for H_2S removal, followed by an Oxygenator/Biotrickling Filter for biological oxidation of H_2S and partial DMS removal. Gas then passes through multiple biofilters containing long-life inorganic media for primary DMS oxidation and a process tank containing an active bioreactor to provide additional treatment of residual sulfur compounds. An Oxygenator system supplies dissolved oxygen to support biological activity and oxidize sulfides. The process utilizes Theia's proprietary Icarus media to provide alkalinity and sulfur treatment without traditional chemical feed systems. The proposed system includes four 12-foot diameter biotrickling filter towers, three modular biofilters, and four process water conditioning tanks. Theia recommends pilot testing prior to implementation of a full-scale system. Refer to Figure 3 for a diagram illustrating the proposed system operation.

Figure 3. Theia Proposed Process Diagram



Consumables

Theia's approach is intended to minimize chemical consumption by relying primarily on biological oxidation processes. Consumables include process water, Icarus media for alkalinity and process support, electricity for pumps, blowers, oxygenation equipment, controls, and sludge handling systems, and potentially BG1 dry media if the polishing system is utilized. The proposal states that process water is continuously recycled to minimize freshwater demand and wastewater generation and may generate excess water when operating on high-humidity LFG streams. Theia estimates Icarus media consumption at approximately 1.0 to 1.5 tons per day, with an estimated operating cost of approximately $100 to $150 per day. Estimated electrical demand for the system is approximately 100 to 150 kVA.

Waste Products

The primary waste stream generated by the system is calcium sulfate sludge, along with smaller quantities of elemental sulfur resulting from biological oxidation of sulfur compounds. Solids are removed from the process water through settling, filtration, and sludge handling equipment and are subsequently dewatered using Theia's EZ-Sludge system. The proposal indicates that the system will generate approximately 2 to 3 tons per day of dewatered sludge consisting primarily of sulfur, calcium sulfate, and biological solids. The dewatered solids may be suitable for land application or use as a soil amendment, subject to site-specific testing and acceptance by end users. The process is also expected to generate approximately 0.8 to 1.0 tons per day of spent Icarus media consisting primarily of iron-based inert material. The proposal indicates that process water is recycled throughout the system, minimizing routine wastewater generation. If utilized, spent polishing media would also require periodic replacement and management

O&M Requirements

O&M activities are expected to include monitoring and operation of the wet scrubber, biotrickling filters, biofilters, process tank bioreactor, oxygenation system, pumps, filters, sludge handling equipment, and process water management system. Periodic sludge removal and dewatering are required, although Theia states that the EZ-Sludge system operates largely through gravity and requires minimal operator attention. The process also includes filtration and solids handling equipment that require routine oversight. Icarus media replenishment and periodic replacement of sludge dewatering filters would be required during normal operation. The system includes continuous monitoring and control of pH, oxidation reduction potential (ORP), dissolved oxygen, pressure, and liquid levels through an Allen-Bradley programmable logic controller (PLC)-based control system with remote telemetry capability. Theia's proposal emphasizes low chemical consumption and limited operator intervention.

Lead Times

Theia provided a budgetary system cost estimate of approximately $3.4 million, with estimated shipping costs of approximately $50,000. The vendor estimates a fabrication and delivery lead time of approximately 20 to 22 weeks following authorization to proceed. Theia also recommends completion of a pilot test prior to implementation and provided a budgetary pilot test estimate of approximately $75,000. The proposed system footprint is estimated to be approximately 50 feet by 120 feet. The vendor indicated that the estimated lead time is driven primarily by fabrication of the treatment system components and procurement of the PLC and control system. Icarus media is a readily available sourced material that is currently produced as a byproduct of another industrial process and is not anticipated to be a supply constraint. According to Theia, once the supply chain is established, Icarus media can be delivered on a routine basis like other bulk process consumables, with on-site inventory maintained to support continuous operation. The vendor noted that alternative horizontal storage boxes may be preferable to the originally proposed storage configuration because they can be loaded and unloaded using conventional site equipment such as a backhoe, simplifying media handling and replenishment activities.

Additional Considerations

During proposal development, Theia indicated that it is willing to provide process design support, technical recommendations, and budgetary pricing for the proposed treatment system. However, Theia's prior experience at other facilities was not extensive, and a large-scale treatment system used at another facility in recent years did not meet the predicted design criteria or treatment targets. At this time, CCL has elected to preclude Theia from consideration or implementation at CCL.

Viability

Theia indicated that biological oxidation can be utilized to treat both H_2S and DMS and proposed a full-scale system specifically developed around the reported LFG conditions. The vendor considers the technology viable for large LFG flows but recommends pilot testing prior to full-scale implementation. Based on the substantial footprint requirements, potential issues with sludge characteristics, ongoing biological process controls, and overall implementation complexity, this technology does not appear to be a viable alternative for implementation.

Equipment List

- LoCHem wet scrubber
- Oxygenator/Biotrickling Filter towers
- Biofilter treatment units
- Biological reactor/process tank
- Process water conditioning tanks
- Oxygenation equipment
- Process water recirculation pumps
- Solids filtration equipment
- EZ-Sludge dewatering system
- Icarus media storage and feed system
- DMS monitoring equipment
- PLC controls and telemetry system
- Associated piping, instrumentation, and controls (PICs)

The Theia alternative represents a fundamental change from the Site's existing media-based sulfur treatment system to a complex biological treatment process. Implementation would require pilot

testing followed by extensive process, civil, structural, mechanical, electrical, controls, water-management, and solids-handling engineering to demonstrate performance and develop a Site-specific design. Substantial permitting, procurement, and fabrication efforts would also be required for the scrubber, biotrickling filters, biofilters, reactors, process tanks, oxygenation systems, pumps, sludge-dewatering equipment, controls, and associated infrastructure. Accordingly, this alternative would likely require a lengthy and technically challenging development period before construction could begin, followed by commissioning, biological startup, performance testing, and operational stabilization before reliable full-scale operation could be established.

Information Not Provided

Theia provided the most comprehensive vendor response among the technologies evaluated, including budgetary capital costs, estimated power requirements, consumable usage rates, anticipated sludge generation rates, treatment footprint, and implementation schedule. However, detailed information regarding long-term sludge disposal costs, maintenance labor requirements, and lifecycle operating costs were not provided and would require further refinement during subsequent design development and pilot testing efforts.

See Appendix E for additional documentation supplied by Theia, LLC.

4.2.5 Axens Heated Catalytic Treatment System

Feasibility Evaluation

Axens' catalytic sulfur treatment process appears technically capable of treating DMS and other organic sulfur compounds but would require substantial supporting infrastructure. The vendor did not provide an implementation timeline, detailed footprint estimate, media life information, or cost estimate. Consequently, design, procurement, installation, and commissioning schedules cannot be fully evaluated based on the available information. The proposed process would require dedicated equipment for H_2S removal, oxygen reduction, gas heating, sulfur adsorption, and nitrogen blanketing.

Although utility requirements were discussed qualitatively, Axens did not provide electrical demand estimates, fuel consumption requirements, or detailed utility consumption data. Based on the proposed configuration, the utility requirements would likely greatly exceed those of the other alternative treatment methods evaluated. Unlike NORIT and UNICAT's adsorption-based systems, Axens process requires dedicated oxygen-reduction equipment, gas heating to approximately 300°F to 350°F prior to DMS treatment. Nitrogen systems would also be required for media loading, vessel blanketing, startup, and maintenance activities. Additional consideration would be needed for potential downstream gas-cooling prior to the existing flare systems. Maintenance activities would require access to sulfur treatment vessels, oxygen reduction equipment, gas heaters, monitoring systems, and media handling areas. Because downtime information was not provided, it is assumed that maintenance and media replacement activities would require periodic process outages. Media life information was not provided by the vendor; therefore, replacement frequencies cannot be estimated. For evaluation purposes, SCS assumes that maintenance outages would be more complex than conventional adsorption systems due to the requirements for oxygen reduction, elevated-temperature operation, nitrogen blanketing, and specialized nickel-media handling procedures.

Waste generation would consist of spent H_2S treatment media and spent nickel-based sulfur treatment media; however, annual disposal quantities could not be estimated because the vendor

did not provide media life, media consumption rates, or sulfur loading capacities. Therefore, waste generation remains uncertain and would require additional vendor input or detailed design analysis.

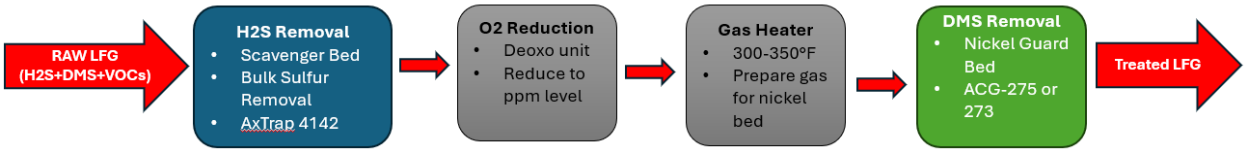
Safety considerations include elevated-temperature operation, oxygen management, nitrogen blanketing, and handling of nickel-bearing media. Capital costs, operating costs, and media life information were not provided by the vendor.

Process

Axens recommends a staged sulfur treatment process consisting of dedicated H_2S and DMS treatment stages. For bulk H_2S removal, Axens recommended utilization of AxTrap 4142 media and indicated that treatment of the anticipated H_2S concentrations is not expected to present a significant technical challenge. Following H_2S treatment, Axens proposes reduction of oxygen concentrations within the LFG stream and heating of the gas to approximately 300 degree Fahrenheit (°F) to 350°F prior to treatment with ACG-275 or ACG-273 nickel-based sulfur guard media for DMS and organic sulfur removal. Axens indicated that nickel-based media is capable of treating a broad range of sulfur compounds including DMS, thiophenes, and other organic sulfur species.

However, the vendor identified the 3% oxygen concentration currently present within the LFG stream as the primary technical challenge because oxygen can deactivate the nickel media, generate excessive heat within the treatment bed, and reduce media life. As a result, Axens does not recommend direct application of nickel-based media under current LFG conditions without additional oxygen reduction measures. Axens also noted that sulfur control upstream of any oxygen reduction catalyst would be critical because sulfur compounds can negatively impact catalyst performance. SCS additionally notes that cooling requirements may need to be evaluated downstream of the heated treatment process prior to discharge into existing HDPE LFG piping and flare infrastructure. Refer to Figure 4 for a diagram illustration of the proposed system operation.

Figure 4. Axens Proposed Process Diagram



Consumables

The primary consumables associated with the Axens process would include AxTrap 4142 media for H_2S removal and ACG-275 or ACG-273 nickel-based media for DMS treatment. Additional consumables may include nitrogen required for media loading, startup, vessel blanketing, and maintenance activities. Depending on the final process configuration, fuel or electrical energy would also be required to heat the LFG stream to the operating temperatures necessary for nickel-based sulfur removal. Axens indicated that the nickel-based media utilized for DMS treatment currently costs approximately $20 per pound

Waste Products

The primary waste streams generated by the Axens process would consist of spent H_2S treatment media and spent nickel-based sulfur guard media containing captured sulfur compounds. Axens

indicated that spent nickel-based media may require specialized handling during unloading because sulfur-laden nickel materials can become reactive when exposed to air. The vendor noted that spent media are commonly wetted and maintained under controlled conditions during removal and may have value for metals recovery and recycling. However, spent nickel-bearing materials would require appropriate characterization prior to disposal or recycling due to the potential presence of nickel sulfides and other captured contaminants.

O&M Requirements

O&M requirements are expected to be more intensive than traditional ambient-temperature media systems due to the elevated operating temperature and sensitivity of the nickel-based media. The process would require continuous monitoring of oxygen concentration, temperature, gas heating systems, and sulfur removal performance. Loading and startup procedures for the nickel-based media would require inert gas management and careful control of oxygen exposure. Based on guidance provided by the vendor, treatment vessels would be purged and maintained under a nitrogen atmosphere during media loading, vessel closure, startup, and certain maintenance activities to prevent oxidation of the media and maintain treatment performance. Additional maintenance requirements would be associated with gas heating systems, oxygen reduction equipment, and sulfur treatment vessels. Axens indicated that startup support and operator training would be provided if the technology were advanced further.

Lead Times

Axens did not provide formal equipment or media lead times, fabrication durations, or a project implementation schedule. The vendor indicated that vessel sizing could begin after final operating conditions are established; however, additional technical development would first be required to confirm oxygen-reduction performance, heating and cooling requirements, sulfur loading, media life, pressure loss, utility demand, safety controls, and compatibility with the existing LFG and flare infrastructure.

The proposed process represents a fundamental change from the Site's existing ambient-temperature media treatment system to a heated catalytic treatment train requiring oxygen reduction, gas heating to approximately 300°F to 350°F, nickel-based sulfur guard vessels, nitrogen blanketing, and potentially downstream gas cooling. Before procurement could begin, the alternative would likely require bench-scale or pilot testing, process-hazard review, permitting, detailed multidisciplinary engineering, Site layout development, and preparation of equipment specifications and bid packages.

The full implementation schedule would also need to include procurement and fabrication of treatment vessels, oxygen-reduction and heating equipment, nitrogen systems, cooling equipment, instrumentation and controls, electrical and utility upgrades, civil improvements, and interconnecting piping. Construction would be followed by system integration, commissioning, controlled media loading, startup under an inert atmosphere, performance testing, and operator training. Because durations for these activities are not available, the overall design-through-operation timeline cannot presently be established but would be expected to be lengthy relative to a conventional media-based replacement system.

Viability

Axens indicated that nickel-based sulfur guard media are capable of removing DMS and other organic sulfur compounds; however, system viability is dependent on successful oxygen reduction

and elevated-temperature operation. The vendor identified oxygen concentration as the primary technical limitation affecting implementation under existing LFG conditions.

Equipment List

- AxTrap 4142 H_2S treatment vessels
- DeOxo oxygen-reduction system
- Gas heating system (300°F-350°F operation)
- ACG-275 or ACG-273 nickel sulfur guard vessels
- Nitrogen storage and blanketing system
- Oxygen monitoring instrumentation
- Temperature monitoring instrumentation
- Sulfur monitoring equipment
- Potential downstream gas cooling system
- DMS monitoring equipment
- Associated piping, instrumentation, and controls (PICs)

The Axens alternative would require an entirely new and highly specialized treatment system rather than reuse of the existing sulfur treatment vessels. The extensive equipment requirements—including oxygen-reduction, high-temperature gas heating, catalytic treatment, nitrogen storage and blanketing, monitoring and controls, and potentially downstream cooling—would require substantial process, mechanical, structural, civil, electrical, controls, and safety engineering. Procurement and fabrication would likely involve multiple specialized vendors and long-lead components, and construction could not begin until the process configuration, Site layout, permitting, safety reviews, utility upgrades, and equipment specifications are sufficiently developed. Following construction, the complexity of inert media handling, elevated-temperature startup, commissioning, and performance testing would further extend the period before reliable operation could be established.

Information Not Provided

Axens provided conceptual process information and identified key operating requirements associated with its catalytic sulfur treatment technology; however, significant information necessary for a comprehensive comparative evaluation was not provided. The vendor did not supply media life projections, media consumption rates, annual waste generation estimates, equipment footprint requirements, electrical or fuel consumption estimates, detailed design or implementation schedules, capital cost estimates, operating cost estimates, maintenance frequencies, staffing requirements, or annual operations and maintenance cost information. As a result, substantial uncertainty remains regarding the long-term operating requirements, lifecycle costs, and implementation feasibility of the proposed treatment system relative to the other technologies evaluated.

See Appendix F for additional documentation supplied by Axens Group.

4.3 OTHER POTENTIAL ALTERNATIVES CONSIDERED

4.3.1 Alternatives Requiring Additional Information

Several vendors expressed interest in the request but did not provide enough information to confirm that their technologies could treat the reported DMS concentrations under anticipated LFG conditions. For example,

- EcoVapor noted concerns related to gas composition, including volatile metals, alkaline compounds, refrigerants, nitrogen compounds, and oxygen content, and stated that additional process information would be needed to determine feasibility. Although EcoVapor did not confirm DMS treatment capabilities, the vendor's gas treatment technologies are generally intended for H_2S reduction in landfill gas application, suggesting that treatment of conventional H2S concentrations may be technically feasible with additional evaluations.

- Calgon Carbon evaluated the application as a carbon adsorption system and requested VOC analytical data to assess the effects of competing compounds on media life but did not determine whether its system could treat DMS. Calgon Carbon offers commercially available carbon products for H_2S removal in landfill gas applications. Therefore, treatment of the reported H_2S concentrations is generally considered feasible using conventional adsorption-based approaches.

- MV Technologies requested basic process information, including gas temperature, pressure, and downstream gas utilization, but did not provide a position on DMS removal. MV Technologies markets sulfur-removal technologies for biogas and landfill gas applications. Treatment of the reported H_2S concentrations would not be expected to be a challenge based on applications of their technology.

Biogas Clean's biological treatment systems are commercially utilized for H_2S removal for biogas streams, with the vendor reporting more than 390 installed systems and H_2S treatment capabilities ranging from approximately 250 to 35,000ppm. Treatment of the reported H_2S concentrations appear technically feasible; the vendor did not provide sufficient information to evaluate DMS treatment performance under current conditions at CCL Since these vendors did not confirm DMS treatment capability, identify a specific DMS treatment strategy, or provide sufficient technical information for detailed evaluation, they were not advanced for further consideration in this study. However, based on publicly available information and the intended applications of their technologies, treatment of the reported H_2S concentrations may be technically feasible and could warrant further evaluation if future efforts focus primarily on replacement of the existing H_2S treatment function rather than comprehensive DMS treatment.

4.3.2 Alternatives Not Advanced for Detailed Evaluation

Based on vendor feedback, Interra Global and Paques explicitly stated that their technologies were not suitable for DMS removal. Interra indicated that its FerroSorp media is effective for H_2S removal but could not currently offer a solution for removing DMS, while Paques stated that its THIOPAQ technology is not recommended for DMS treatment and suggested activated carbon-based alternatives instead.

Merichem Technologies subsequently confirmed that its SULFURTRAP process cannot remove DMS. In addition, the vendor noted that treatment of the reported LFG flow rates would require multiple parallel treatment trains due to the low-pressure nature of the gas stream, resulting in a system that would likely be prohibitively expensive for landfill applications. Merichem further stated that compression of the LFG to approximately 100 psig would be necessary to allow treatment in a single lead-lag configuration and concluded that the application does not appear to be a viable candidate for treatment using SULFURTRAP technology.

As mentioned in Section 4.2.3 Theia is also removed from consideration due to prior inadequacies in previous treatment applications. While the technology appears capable of sulfur treatment, concerns with the substantial water-management requirements, sludge generation. Biological process controls, operational complexity, and infrastructure demands associated with the system, limit its suitability for application. Consequently, these vendors were not included in the detailed evaluation of potential treatment technologies.

4.4 COMPARATIVE EVALUATION

4.4.1 Summary of Advantages and Disadvantages by Vendor

Table 3. Summary of Advantages and Disadvantages by Vendor

Alternative	Advantages	Disadvantages and Implementation Considerations
NORIT H_2S-Only Replacement	• Uses a conventional, commercially available H_2S adsorption approach. • Could provide media service intervals exceeding one year. • Would replace aging vessels and add improved controls and remote monitoring. • Expected to require less new process infrastructure and fit within or adjacent to the existing treatment area.	• Does not provide dedicated DMS treatment or independently achieve the 60-ppmv monthly total-sulfur limit. • Final viability depends on confirming safe vessel materials, configuration, monitoring, and safeguards. • Engineering, permitting, procurement, construction, and startup would still be required for the replacement vessels and associated improvements.
NORIT H_2S and DMS	• Provides separate H_2S, VOC, and DMS treatment stages using commercially available adsorption media. • Includes commercially available DMS monitoring options.	• Requires a substantially new treatment train with dehydration, condensate management, reheating, regenerative VOC removal, multiple vessels, controls, utilities, and civil improvements. • Projected RB-4 replacement approximately every 17 days and annual RB-4 use of approximately 3,231 tons may

Alternative	Advantages	Disadvantages and Implementation Considerations
		create significant operational, storage, transportation, and disposal constraints. • Performance is highly dependent on moisture and VOC control. • Electrical demand, installed cost, waste classification, and the full implementation schedule remain undefined. • Likely requires lengthy testing, engineering, permitting, procurement, construction, commissioning, and startup.
UNICAT	• Provides dedicated H_2S, VOC, and DMS treatment stages. • Does not require dehydration, oxygen reduction, or elevated-temperature operation. • Vendor projects approximately 40-month H_2S media life and outlet sulfur concentrations below the treatment target.	• Requires a new six-vessel system, multiple media types, condensate management, monitoring, potential water injection, and substantial Site integration. • VOC and DMS media may require replacement every one to two months, creating significant media-handling and waste-management demands. • Only media costs and lead times were provided; installed-system cost, disposal requirements, and the full design-through-startup schedule remain undefined. • Requires significant engineering, permitting, procurement, fabrication, construction, commissioning, and operator training before operation.
Theia Biological Treatment	• Uses biological treatment rather than large fixed adsorption beds. • Allows continuous Icarus-media replenishment, reducing large periodic media-changeout events. • Vendor provided the most complete preliminary system	• Represents a fundamental technology change to a complex biological treatment process and has the largest defined footprint. • Requires pilot testing, extensive multidisciplinary engineering, permitting, specialized procurement, construction, biological startup, and operational stabilization.

Alternative	Advantages	Disadvantages and Implementation Considerations
	cost, power demand, footprint, and fabrication information.	• Generates substantial sludge and spent media requiring continuous handling and disposal. • Requires biological process, water, oxygenation, and solids-management systems.
Axens Heated Catalytic Treatment	• Vendor indicates the process can remove DMS and a broad range of organic sulfur compounds. • Uses dedicated H_2S and DMS treatment stages and potentially high-capacity nickel-based sulfur guard media.	• Represents an entirely new, highly specialized heated catalytic system requiring oxygen reduction, gas heating to approximately 300°F–350°F, nitrogen blanketing, specialized nickel-media handling, and potentially downstream cooling. • Requires substantial technical development, multidisciplinary engineering, safety review, permitting, utility upgrades, specialized procurement, construction, commissioning, and controlled startup. • Oxygen concentration is a primary technical limitation. • The vendor did not provide media life, consumption rates, footprint, costs, or an implementation schedule. • The design-through-operation timeline is expected to be lengthy relative to a conventional media-based replacement system.

4.4.2 Treatment Options Comparison

The table below compares the various treatment options for several parameters as shown below.

Table 4. Treatment Option Comparison

Parameter	NORIT (H_2S)	NORIT (H_2S & DMS)	UNICAT	THEIA	AXENS
Primary Treatment Method	Activated Carbon Adsorption; Upstream Gas Conditioning	Activated Carbon Adsorption; Upstream Gas Conditioning	Iron Oxide + Activated Carbon Adsorption	Biological Oxidation	Heated Catalytic Sulfur Removal
H_2S Treatment Method	BG-1 Carbon	BG-1 Carbon	SR-101D Iron Oxide	LoChem Wet Scrub	AxTrap 4142
DMS Treatment Method	NA	RB-4 Carbon	HRU-CSP (VOC Media) TSR-12SF (DMS Media)	Biotrickling Filters / Biofilters	Nickel Guard Bed
Primary Consumable	BG-1	BG-1; RB-4	SR-101D; HRU-CSP & TSR-12SF Media	Icarus Media	AxTrap 4142; ACG-275/273 + Utility Power
Approx. Media Replacement Frequency (H_2S)	>1 year (concept 26-ft I.D. lead-lag vessel config.)	>1 year (concept 26-ft I.D. lead-lag vessel config.)	~40 months (with existing 16-ft I.D. vessel config)	Continuous replenishment of Icarus Media	Not provided
Approx. Media Replacement Frequency (DMS)	N/A	17 days per vessel	HRU-CSP & TSR-12SF: ~1-2 months		Not provided
H_2S Media Consumption Rate	(1) 0.5 to 1 ton/day	(1) 0.5 to 1 ton/day	(1) 0.4 to 0.6 ton/day	1.0-1.5 tons/day Icarus Media	Not provided
DMS Media Consumption Rate	N/A	8.85 tons/day Activated Carbon	2.7-4.3 tons/day		Not provided
Annual H_2S Media Consumption	~360 tons/year	(1) ~360 tons/year	(1) ~150-200 tons/year	365-548 tons/year Icarus Media	Not provided
Annual DMS Media Consumption	N/A	3,231 tons/year	1,000-1,600 tons/year		Not provided
Sludge Generation	None	None	None	2-3 tons/day	None Expected

Parameter	NORIT (H_2S)	NORIT (H_2S & DMS)	UNICAT	THEIA	AXENS
Water Requirement	None expected	Dehydration Required	Saturated Gas Required; Water Injection May Be Required	Minimal Makeup Water	None Expected
Moisture Sensitivity	Moisture of 60-100% needed for BG-1	Moisture of 60-100% needed for BG-1; dehydration needed for RB-4	Moisture Required for SR-101D Performance	Moisture Required	Not Identified
Oxygen Sensitivity	Low	Low	Required	Low	High
Additional Utility Requirements	NA	Dehydration, Reheat, and VOC Removal System	Condensate Management; Potential Water Injection	Pumps, Blowers, Oxygenation	Oxygen Reduction; Gas Heating; Nitrogen use
Power Demand	(2) Minimal to Moderate	(2) Moderate to High	(2) Low	100-150 kVA	(2) High
Estimated Footprint	Existing treatment footprint (up to six replacement vessels)	3,000-4,500 sq ft H_2S train plus additional footprint for dehydration, VOC removal, and DMS treatment equipment	Six 20-ft ID treatment vessels; final footprint dependent on layout	~50 ft × 120 ft	Footprint not provided; expected to exceed conventional adsorption systems due to heaters, DeOxo equipment, nitrogen systems, and sulfur guard vessels
(2) Maintenance Access Needed	Moderate Required for media replacement, vessel inspection, and monitoring equipment	High Access to dehydration equipment, condensate management, VOC treatment equipment, DMS vessels, and frequent media changeouts	Moderate to High Access to six treatment vessels for media replacement	High Access for pumps, blowers, sludge handling, process water systems, biofilters, and media storage	High Access for heaters, oxygen reduction system, nitrogen systems, and sulfur guard beds

Parameter	NORIT (H_2S)	NORIT (H_2S & DMS)	UNICAT	THEIA	AXENS
[2] System Downtime for Maintenance	Minimal	Low to Moderate	Low to Moderate	Low	Moderate
[3] Initial Capital Cost	[2] Lower than DMS alternatives	Not provided	[1] ~$8.50M (media only)	~$3.4M (system)	Not provided
Estimated Annual Media Cost	Not evaluated	[1] $31.3M (RB-4 only)	[1] ~$29M-$57M (all media)	[1] ~$36,500-$54,750	Not provided
Pilot Test	NA	1-year	1-year	1-year	1-year
Lead Time Provided	BG-1: 1-2 months	BG-1: 1-2 months RB-4: 6 months	13-25 weeks (initial media) 4-6 weeks (changeouts)	20-22 Weeks (full system)	Not provided
Design Duration (estimated)	8-months	1-year	Not provided	Not provided	Not provided
Manufacturer Fabrication (estimated)	1-year	1-year	13-25 weeks media procurement; vessel fabrication by third party	20-22 weeks	Not provided
Installation (estimated)	8-months	8-months	[2] ~6-8 months	[2] ~6-8 months	[2] ~8-12 months
Permit (estimated)	2-years +	2-years +	Not provided	Not provided	Not provided
Safety	Standard activated-carbon vessel operations; media replacement activities.	Frequent media replacement, condensate handling, chilling & reheating gas streams, VOC-treatment equipment	Frequent media replacement; sulfur-bearing media handling; saturated gas operation.	Biological process operation; sludge handling; process-water management.	Elevated-temperature operation; oxygen reduction; nitrogen blanketing; nickel-media handling.

Notes:

[1] Calculated based on proposed media consumption rate. Actual media consumption and replacement costs may vary.

[2] Planning-level SCS estimates provided for comparative evaluation purposes only. Vendor-specific design, manufacturing, installation, and permitting schedules were generally not provided and actual project timelines may vary substantially based on final design and regulatory requirements.

[3] Capital cost information was not provided on a consistent basis by vendors and therefore values should not be compared directly

5.0 CONCLUSION AND RECOMMENDATIONS

The conclusions and recommendations presented in this section are preliminary and reflect the information available as of the date of this report, including the current status of the ongoing vessel investigation and the vendor-provided information evaluated in Section 4. The investigation has not yet developed a complete understanding of all conditions that may have contributed to the prior thermal event. In addition, several treatment alternatives require additional Site-specific testing, technical vendor information, testing, and design and engineering development before their practical feasibility at CCL can be determined.

Accordingly, the comparative findings, preferred alternatives, and recommended next steps may be revised as the vessel investigation is completed, additional Site-specific data become available, and vendors provide further information regarding performance, safety, equipment requirements, costs, and implementation schedules. Any decision to advance a treatment alternative should therefore be based on the complete investigation record and subsequent engineering evaluation rather than solely on the preliminary findings presented in this report

5.1 CONCLUSIONS

This evaluation identified multiple technologies that vendors represented as potentially technically capable of reducing H_2S and DMS concentrations, and therefore sulfur oxide concentrations, in the LFG stream to levels necessary to support compliance with the Site's sulfur treatment objectives. Through outreach to numerous technology providers, four (4) vendors ultimately presented treatment approaches warranting this evaluation, including NORIT Activated Carbon, UNICAT Catalyst Technologies, Theia, LLC, and Axens Group. Each vendor proposed a different treatment strategy and indicated that DMS removal is technically achievable using commercially available technologies. Although included within this comparison, Theia has been removed from further consideration by CCL based on previous treatment performance concerns. However, the vendors' projections have not been demonstrated under sustained Site-specific operating conditions, and additional engineering and, in some cases, bench- or pilot-scale testing would be required before reliable control efficiency and practical feasibility can be established.

A consistent finding throughout the evaluation was that DMS, rather than H_2S, represents the primary treatment challenge at CCL. Multiple vendors indicated that removal of the reported H_2S concentrations can be achieved using conventional treatment approaches and relatively long media service intervals, whereas DMS removal changes system complexity, media consumption, operating costs, and overall treatment feasibility. Vendors also identified competitive adsorption from VOCs, particularly acetone, ketones, and BTEX compounds, as a significant factor impacting DMS treatment performance and media life. In several cases, vendors revised their treatment approaches to include dedicated VOC-management strategies intended to improve DMS removal efficiency and extend media service life.

The evaluation further indicated that moisture content, VOC loading, oxygen concentrations, LFG flow rates, and monitoring requirements can substantially influence treatment performance and operational costs. While several technologies appear technically feasible, implementation complexity varies considerably. Proposed treatment systems ranged from relatively conventional adsorption-based approaches utilizing replaceable media to biological treatment systems and catalytic treatment processes requiring oxygen reduction, elevated temperatures, specialized media handling procedures, or additional process infrastructure.

A second consistent finding was the limited availability of documented, full-scale LFG treatment systems specifically designed for DMS removal under conditions comparable to those currently observed at CCL. While vendors provided technical evaluations, conceptual designs, and projected treatment performance, relatively few operating case studies were identified involving LFG streams with similarly elevated DMS concentrations, VOC loading, and flow rates. Consequently, uncertainty remains regarding long-term media performance, replacement frequency, operating costs, and treatment effectiveness under sustained site operating conditions.

The alternatives evaluated vary substantially in footprint requirements and overall implementation complexity. The existing H_2S treatment system upgrade alternative would require the smallest footprint and could largely utilize the existing treatment area. The integrated adsorption-based alternatives proposed by NORIT and UNICAT would require installation of multiple treatment vessels and associated equipment, with the NORIT DMS treatment approach requiring additional space for dehydration, VOC removal, and gas reheating infrastructure. Theia's biological treatment system would require an estimated footprint of approximately 50 feet by 120 feet. Axens did not provide a footprint estimate; however, based on the proposed oxygen reduction equipment, gas heating systems, sulfur guard vessels, and supporting infrastructure, the overall footprint would be expected to exceed that of a conventional adsorption-based treatment system.

Implementation schedules also vary significantly between alternatives. The existing H_2S treatment system upgrade would primarily involve replacement of vessels and associated infrastructure and therefore represents one of the least complex implementation approaches. NORIT reported media lead times ranging from approximately 4 to 24 weeks, while UNICAT reported initial media lead times ranging from approximately 13 to 25 weeks. Theia provided the most complete implementation schedule, estimating approximately 20 to 22 weeks for fabrication and delivery of the proposed treatment system. Axens did not provide implementation or procurement schedules, resulting in greater uncertainty regarding project planning and execution.

For several vendors, design, permitting, and installation durations were not provided and were therefore estimated by SCS for comparative evaluation purposes only. In addition to treatment performance and footprint requirements, operational logistics should be considered during future alternative selection. Technologies requiring frequent media replacement may result in increased truck traffic, media handling activities, and temporary storage requirements compared to the alternatives that utilize biological treatment or treatment media with increased time between media changeouts.

Based on the information available at the time of this evaluation, multiple vendors have identified technologies that they represent as theoretically and technically capable of reducing sulfur concentrations within the LFG stream; however, each alternative presents unique advantages, limitations, and implementation challenges and the vendors' projected performance has not been demonstrated under sustained Site-specific operating conditions.

Based on the currently available information, upgrading the existing H_2S treatment system appears to offer the most readily implementable alternative. Although it would not provide dedicated DMS treatment. The NORIT and UNICAT adsorption-based approaches utilize commercially available treatment media and conventional treatment equipment but would require significant media replacement requirements and operating costs, and their practicable feasibility at CCL has not yet been established. The Theia biological treatment system would reduce dependence on frequent media replacement but the system is not recommended for further evaluation because of its biological process controls, sludge handling requirements, larger equipment footprint, and other

implementation considerations. The practical feasibility of the Axens alternative also remains uncertain because it presents the most operationally complex treatment approach evaluated due to the need for oxygen reduction, elevated-temperature operation, nitrogen blanketing procedures, and specialized sulfur media handling.

As a result, future alternative selection should consider not only sulfur removal performance, but also footprint availability, procurement and implementation schedule, utility requirements, maintenance requirements, waste generation, long-term operating costs, and overall operational complexity. Additional design development, vendor engagement, pilot testing, and implementation planning may be warranted prior to selection of a final treatment strategy.

5.2 RECOMMENDED NEXT STEPS

Based on the presently available information, CCL should advance a phased evaluation rather than immediately select a full-scale treatment system. Given the initial findings of Condition 3(b) vessel investigation, CCL should advance the conventional H_2S-only replacement alternative to preliminary engineering because it most directly restores the function of the existing treatment system and appears to require less new process infrastructure than the combined H_2S and DMS alternatives, and addresses the safety and design criteria for any replacement or alternative system.

Preliminary engineering for the H_2S-only replacement alternative should confirm vessel material and configuration, thermal monitoring and safeguards, treatment capacity, media life, equipment layout, connections to existing LFG infrastructure, utilities, permitting requirements, media-changeout procedures, waste-management requirements, cost, and a design-through-startup schedule. The resulting design basis should be reviewed against the completed vessel investigation before CCL authorizes detailed design or equipment procurement.

For alternatives intended to treat DMS or total sulfur, CCL should request focused supplemental information from NORIT, UNICAT, and Axens sufficient to resolve the major data gaps identified in Section 4, including guaranteed treatment performance, media consumption and changeout duration, utility demand, equipment footprint, waste characterization and disposal, installed and operating costs, safety requirements, and complete implementation schedules. Bench-scale or pilot testing should be required before full-scale selection where vendor performance has not been demonstrated under LFG conditions representative of the Site. Any testing program should establish defined performance, safety, media-life, waste-generation, and operability criteria before it begins.

Following completion of the vessel investigation, preliminary engineering, supplemental vendor evaluation, and any required testing, CCL should update the comparative evaluation and select the alternative or phased combination of alternatives that best satisfies Site safety, feasibility, sulfur-reduction, operational, permitting, schedule, and cost considerations. Detailed design, permitting, procurement, construction, commissioning, and performance testing should proceed only after that decision point. These recommended steps are preliminary and may be revised as additional investigation and vendor information become available.

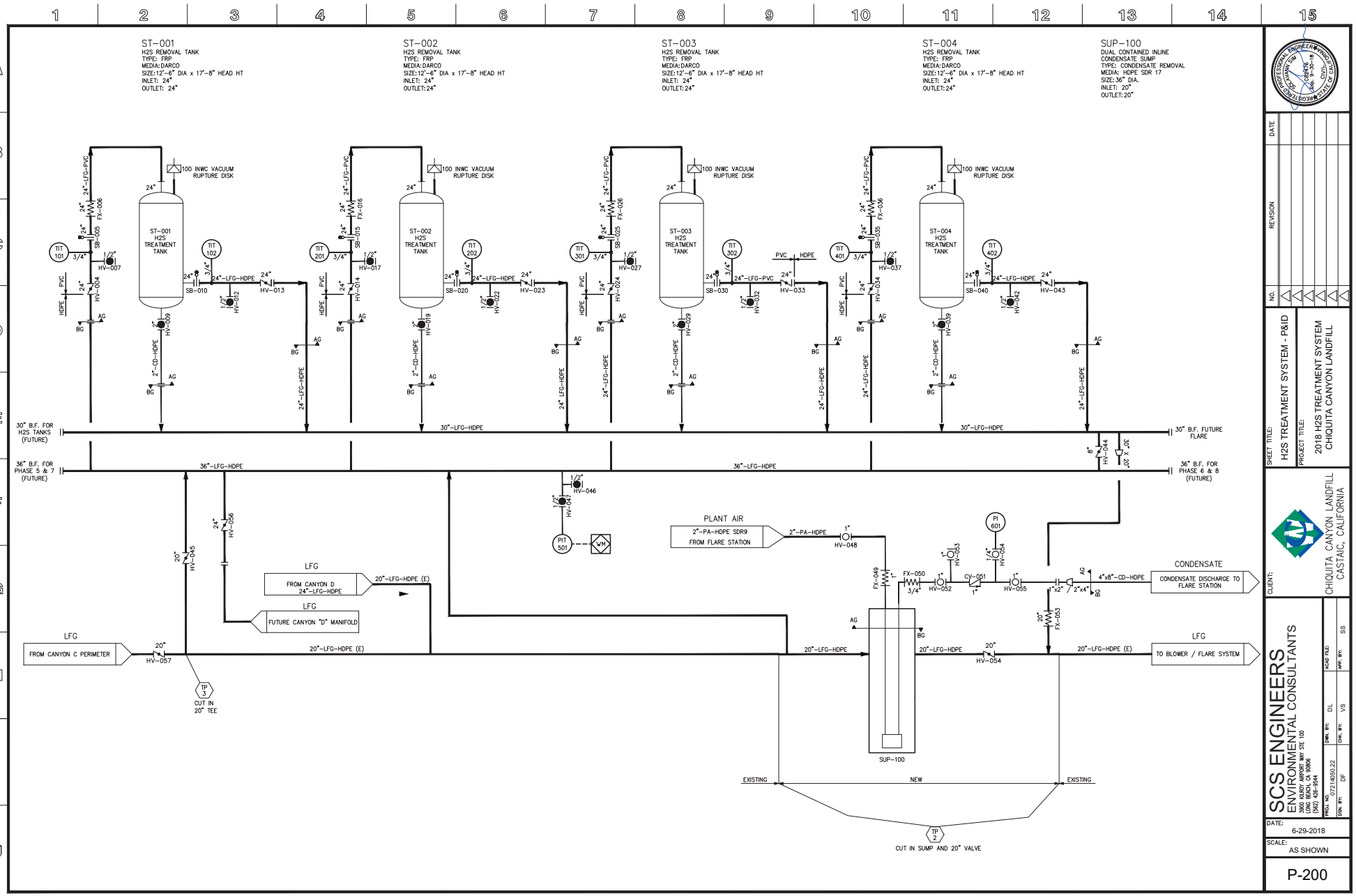
5.3 VENDOR RESPONSE SUMMARY TABLE

Table 5. Vendor Response Summary

Vendor	Response to H_2S Removal?	Response to DMS Removal?	Notes:
NORIT Activated Carbon	Yes	Yes	Proposed BG-1 media for H_2S removal, dehydration, and RB-4 media specifically for DMS removal. Discussed previous landfill applications involving DMS treatment
UNICAT Catalyst Technologies	Yes	Yes	Confirmed they have sorbent options capable of treating the reported DMS concentrations and developed a TSR-12SF DMS-specific treatment proposal.
Theia, LLC	Yes	Yes	Researched the DMS application and provided a conceptual biological treatment system specifically designed to address both H_2S and DMS.
Axens Group	Yes	Yes	Confirmed DMS removal is technically possible using ACG-275/ACG-273 nickel media, although oxygen reduction and heating would likely be required.
Biogas	Yes	Inconclusive	Indicated further evaluation and testing would be needed. Did not confirm DMS treatment capability.
EcoVapor	Yes	Inconclusive	Believed treatment might be possible but required significantly more gas composition information before determining feasibility
Calgon Carbon	Yes	Inconclusive	Requested TO-15 data and discussed VOC impacts on media life but never confirmed DMS treatment capability.
MV Technologies	Yes	Inconclusive	Requested temperature, pressure, and process information but never provided a position regarding DMS treatment.
Interra Global	Yes	No	Explicitly stated FerroSorp removes H_2S but not DMS. Recommended UNICAT TSR-12SF instead.
Paques	Yes	No	Explicitly stated THIOPAQ is not recommended for DMS removal and suggested activated carbon technologies instead. Confirmed SULFURTRAP cannot remove DMS and concluded the application is not viable for their technology
Merichem	Yes	No	Confirmed SULFURTRAP cannot remove DMS and concluded the application is not viable for their technology.
Streamline Innovations	Yes	No	Historical DMS work exists through SCS Reaction Committee study, but no current 2026 DMS treatment proposal was provided during this vendor outreach effort.
SLB	No Response	No Response	
DMT Clear Gas Solutions	No Response	No Response	
CECO Environmental	No Response	No Response	

Appendix A

2018 H2S Treatment System Design Drawings



N:\FieldService\JOBS by Client\Waste Connections\Chiquita Canyon Landfill\072140S0.22 WC, 2017 Centralized H2S\Deliverables\Drawings\P-200.dwg Sep 12, 2018 - 4:20pm By: 448ahk

NO.	REVISION	DATE

SHEET TITLE: H2S TREATMENT SYSTEM - P&ID

PROJECT TITLE: 2018 H2S TREATMENT SYSTEM CHIQUITA CANYON LANDFILL

CLIENT: CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA

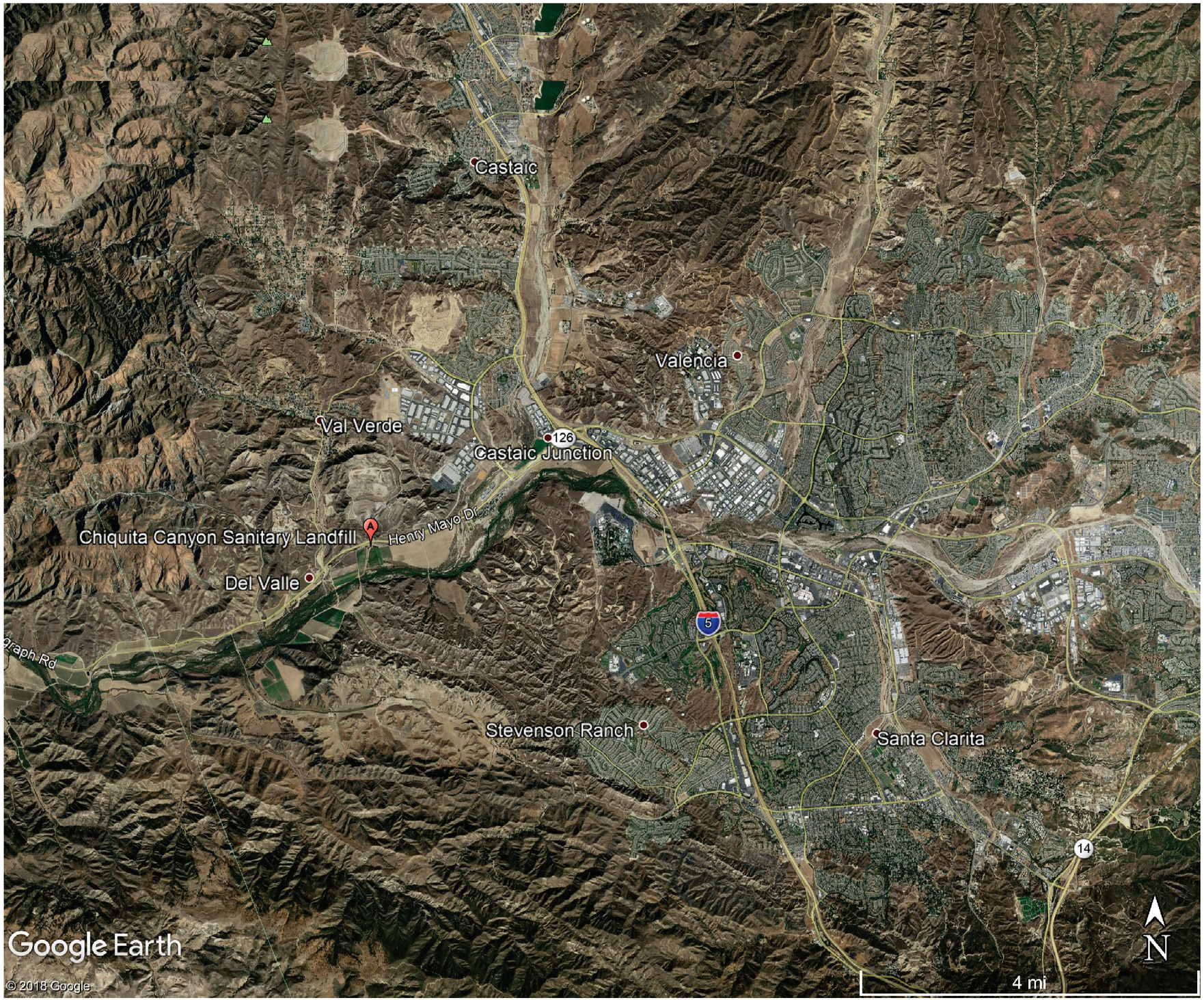
SCS ENGINEERS
ENVIRONMENTAL CONSULTANTS
3900 KILROY AIRPORT WAY STE 100
LONG BEACH, CA 90806
(562) 426-9544

PROJ. NO: 072140S0.22 | DSN. BY: DF | DRN. BY: DL | CHK. BY: VS | APP. BY: SS | ACAD FILE:

DATE: 6-29-2018

SCALE: AS SHOWN

P-200



NO.	REVISION	DATE
A	ISSUED FOR PERMIT	3/29/18
B		
C		
D		
E		

SHEET TITLE: **SITE LOCATION MAP**

PROJECT TITLE: **H2S TREATMENT SYSTEM CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA**

CLIENT: **CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA**

SCS ENGINEERS
ENVIRONMENTAL CONSULTANTS
3900 KILROY AIRPORT WAY STE 100
LONG BEACH, CA 90806
(562) 426-9544

PROJ. NO.	DWN. BY:	ACAD FILE:
07214050.22	DL	FIGURE 1
DSN. BY:	CHK. BY:	APP. BY:
DF	SS	SS

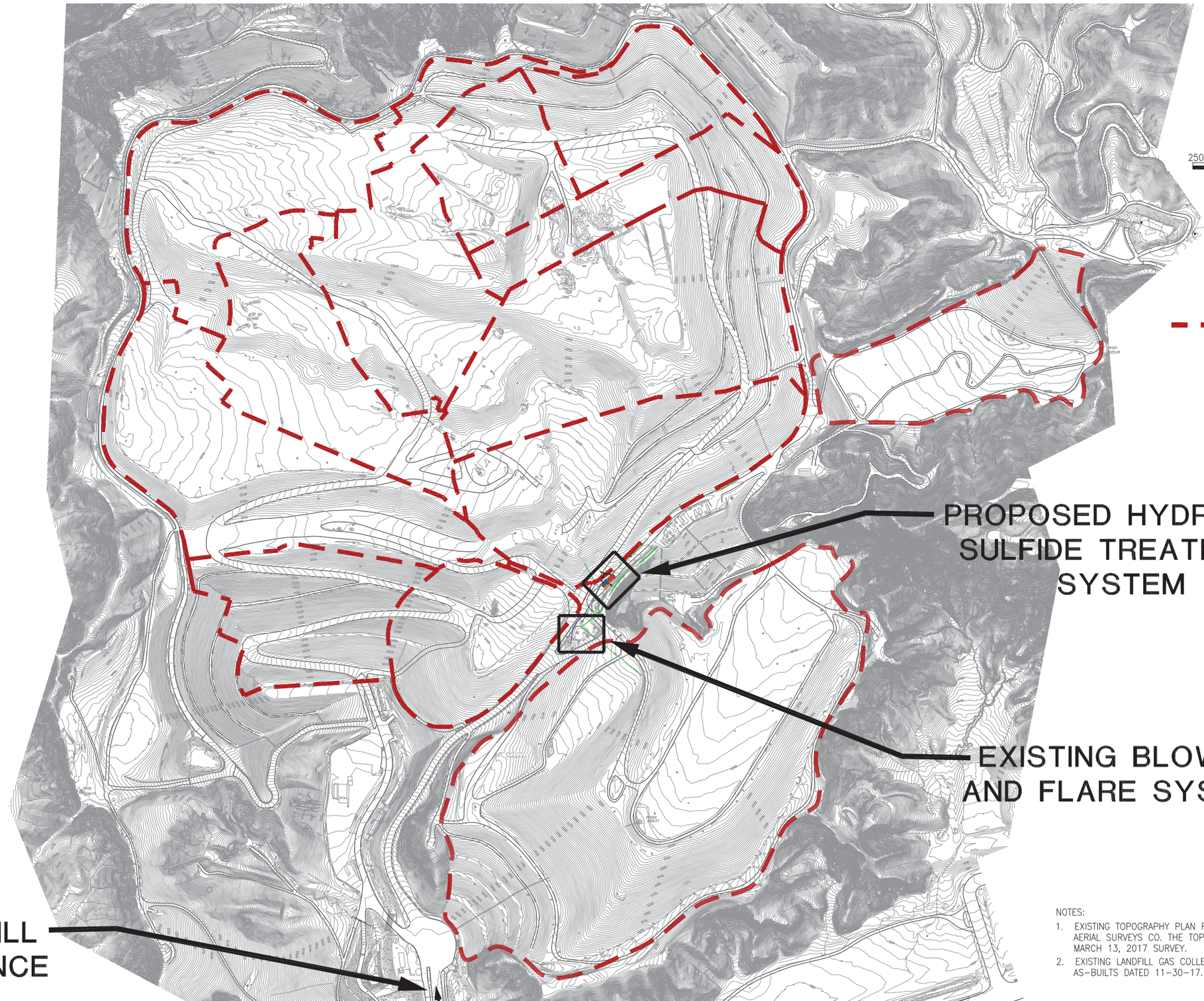
DATE: **2-1-2018**

SCALE: **AS SHOWN**

Figure 1

1 of 4

N:\FieldService\JOBS by Client\Waste Connections\Chiquita Canyon Landfill\07214050.22 WC, 2017 Centralized H2S\Deliverables\Drawings\FIGURE 1.dwg Apr 04, 2018 - 9:38am By: dlacarra



NOTES:

1. EXISTING TOPOGRAPHY PLAN FURNISHED BY COOPER AERIAL SURVEYS CO. THE TOPOGRAPHY DATA IS BASED ON MARCH 13, 2017 SURVEY.
2. EXISTING LANDFILL GAS COLLECTION SYSTEM BASED ON AS-BUILTS DATED 11-30-17.

NO.	REVISION	DATE
1	ISSUED FOR PERMIT	3/29/18

SHEET TITLE: PROJECT LOCATION MAP

PROJECT TITLE: H2S TREATMENT SYSTEM
CHIQUITA CANYON LANDFILL
CASTAIC, CALIFORNIA

CLIENT: CHIQUITA CANYON LANDFILL
CASTAIC, CALIFORNIA

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ENVIRONMENTAL CONSULTANTS
3900 KILROY AIRPORT WAY STE 100
LONG BEACH, CA 90806
(562) 426-9544

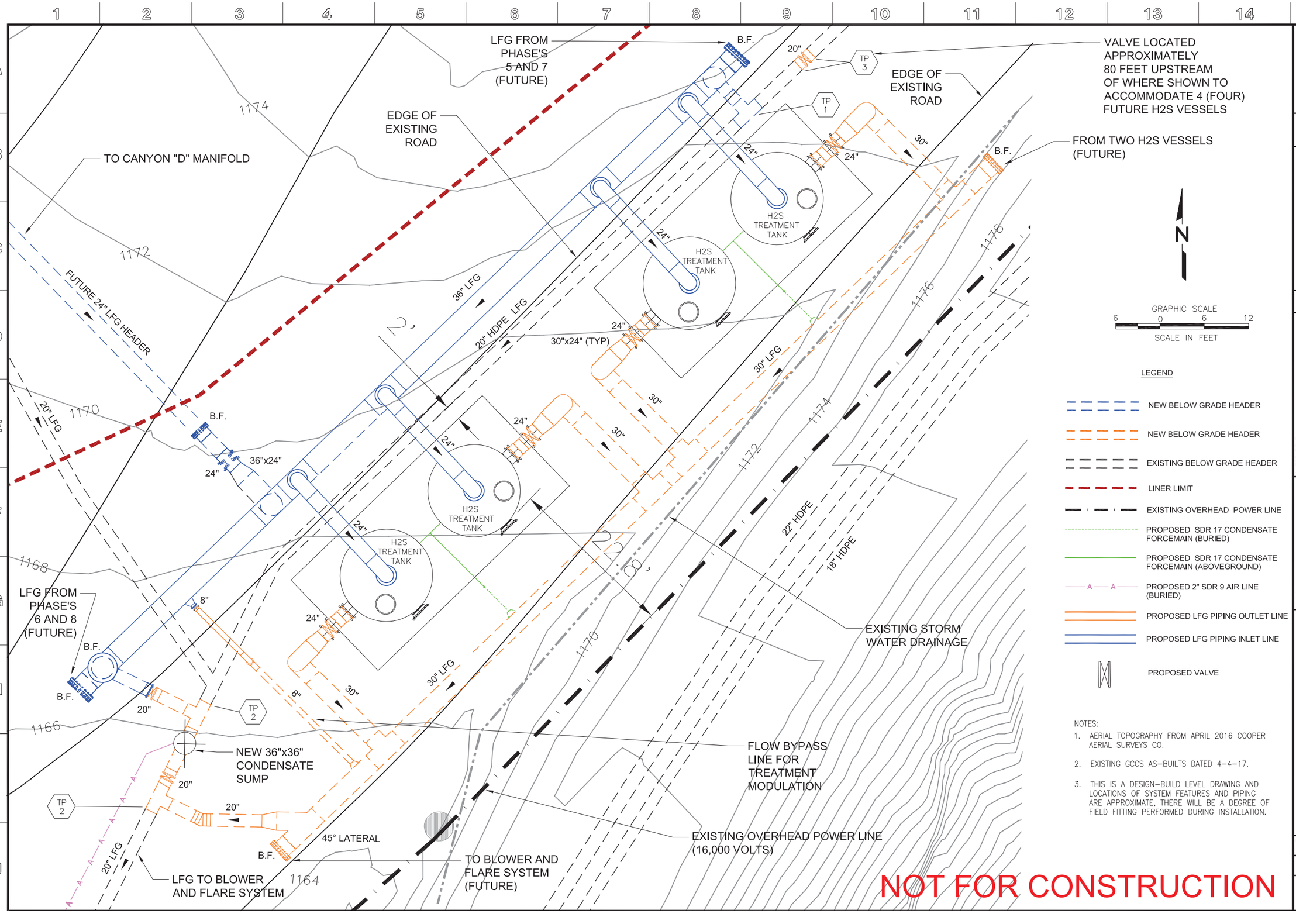
PROJ. NO: 07214050.22 | DWN. BY: DL | ACAD FILE: FIGURE 2 | APP. BY: SS
DSN. BY: DF | CHK. BY: SS

DATE: 2-1-2018

SCALE: 1"=500'

Figure 2
2 of 4

N:\FieldService\JOBS by Client\Waste Connections\Chiquita Canyon Landfill\07214050.22 WC, 2017 Centralized H2S\Deliverables\Drawings\FIGURE 2.dwg Apr 04, 2018 - 9:53am By: dlacorra



NOTES:

1. AERIAL TOPOGRAPHY FROM APRIL 2016 COOPER AERIAL SURVEYS CO.
2. EXISTING GCCS AS-BUILTS DATED 4-4-17.
3. THIS IS A DESIGN-BUILD LEVEL DRAWING AND LOCATIONS OF SYSTEM FEATURES AND PIPING ARE APPROXIMATE, THERE WILL BE A DEGREE OF FIELD FITTING PERFORMED DURING INSTALLATION.

NOT FOR CONSTRUCTION

NO.	REVISION	DATE
1	ISSUED FOR PERMIT	3/29/18

SHEET TITLE: **H2S SYSTEM AND PIPING**

PROJECT TITLE: **H2S TREATMENT SYSTEM CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA**

CLIENT: **CHIQUITA CANYON LANDFILL CASTAIC, CALIFORNIA**

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ENVIRONMENTAL CONSULTANTS
3900 KILROY AIRPORT WAY STE 100
LONG BEACH, CA 90806
(562) 426-9544

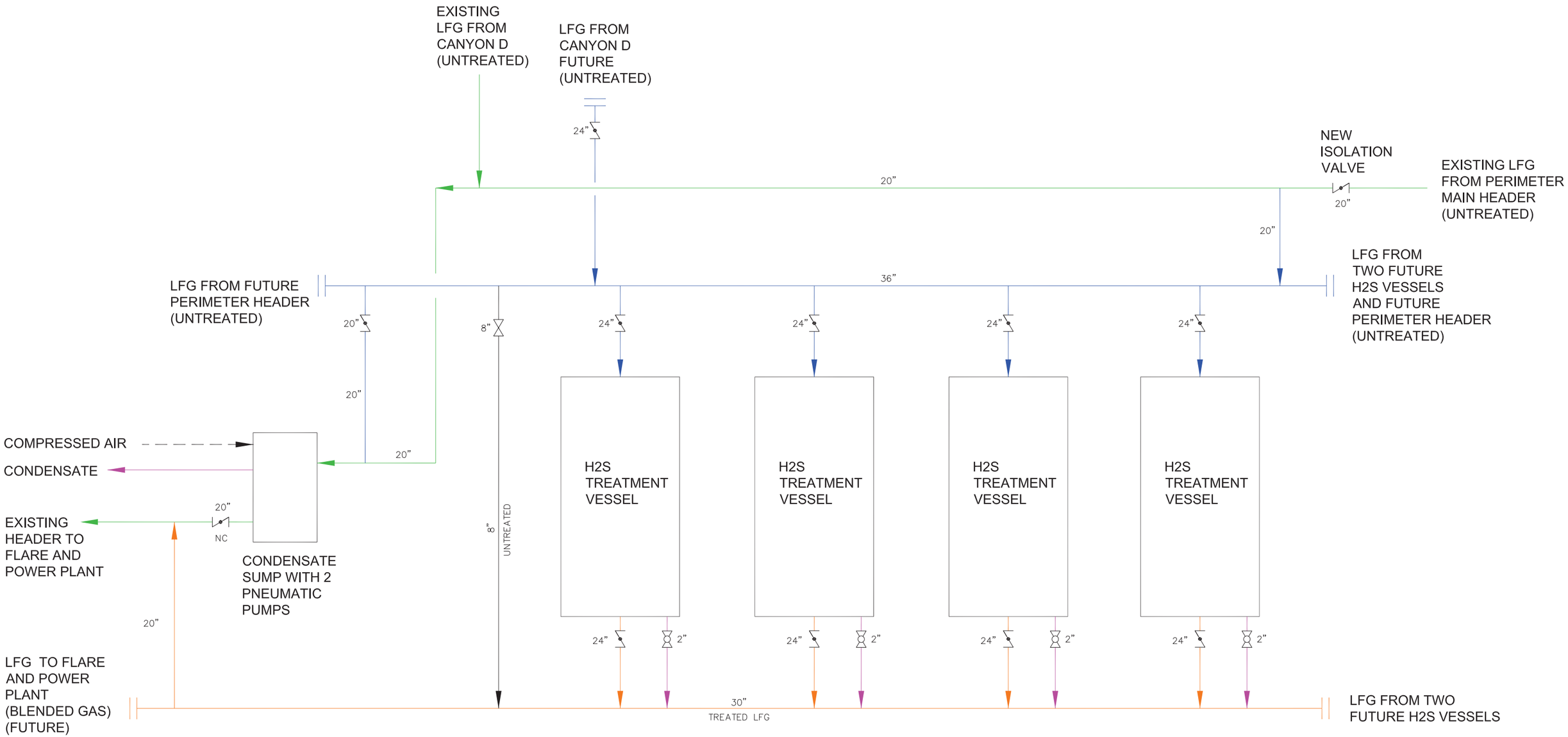
ACAD FILE: FIGURE 3
DWN. BY: DL
CHK. BY: SS
APP. BY: SS
PROJ. NO. 07214050.22
DSN. BY: DF

DATE: 2-1-2018

SCALE: AS SHOWN

Figure 3
3 of 4

N:\FieldService\JOBS by Client\Waste Connections\Chiquita Canyon Landfill\07214050.22 WC, 2017 Centralized H2S\Deliverables\Drawings\FIGURE 3.dwg Apr 04, 2018 - 9:46am By: dlacarra



LEGEND

- EXISTING HEADER
- PROPOSED LFG PIPING INLET LINE
- PROPOSED LFG PIPING OUTLET LINE
- PROPOSED CONDENSATE LINE
- PROPOSED COMPRESSED AIR LINE
- PROPOSED BYPASS LINE
- BUTTERFLY VALVE
- BALL VALVE
- V-PORT GATE VALVE
- BLIND FLANGE FOR FUTURE SYSTEM EXPANSION
- NC — NORMALLY CLOSED

SCS ENGINEERS
ENVIRONMENTAL CONSULTANTS
3900 KILROY AIRPORT WAY, SUITE 100
LONG BEACH, CALIFORNIA 90806
PH. (562) 426-9544

PROJ. NO.	DWN. BY:	ACAD FILE:
07214050.22	DL	FIGURE 4
DSN. BY:	CHK. BY:	APP. BY:
DF	SS	SS

CLIENT:
CHIQUITA CANYON LANDFILL
CASTAIC, CALIFORNIA

SHEET TITLE:
PROCESS FLOW DIAGRAM

PROJECT TITLE:
H2S TREATMENT SYSTEM
CHIQUITA CANYON LANDFILL
CASTAIC, CALIFORNIA

DATE: 03/28/2018
SCALE: NTS
FIGURE:
FIGURE 4
4 of 4

Appendix B

Chiquita Canyon Landfill – Landfill Gas Sample Results

TO-15 – FL-2009

CHIQUITA CANYON LANDFILL
LANDFILL GAS SAMPLE RESULTS
TO-15 - FL-2009

CLIENT_SAMPLE_NUMBER	DATE_COLLECTED	METHOD	CAS_NUMBER	COMPOUND_NAME	CONCENTRATION	UNITS	DILUTION_FACTOR
FL-2009 Inlet	4/2/2026	TO15	75-71-8	Freon 12	<1.50	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	74-87-3	Chloromethane	2.20	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	76-14-2	Freon 114	<1.10	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-01-04	Vinyl Chloride	<1.50	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	106-99-0	1,3-Butadiene	<1.80	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	74-83-9	Bromomethane	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-00-3	Chloroethane	<1.50	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	67-64-1	Acetone	83.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-69-4	Freon 11	<1.40	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	67-63-0	Isopropyl Alcohol	28.00	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-35-4	1,1-Dichloroethene	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-09-2	Methylene Chloride	<2.20	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-15-0	Carbon Disulfide	<1.30	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	76-13-1	Freon 113	<1.00	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	156-60-5	trans-1,2-Dichloroethene	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-34-3	1,1-Dichloroethane	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	1634-04-4	MTBE	<2.10	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	108-05-4	Vinyl Acetate	<2.60	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	78-93-3	2-Butanone	37.80	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	156-59-2	cis-1,2-Dichloroethene	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	110-54-3	n-Hexane	<2.20	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	67-66-3	Chloroform	<1.60	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	141-78-6	Ethyl Acetate	4.25	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	109-99-9	Tetrahydrofuran	32.40	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	107-06-2	1,2-Dichloroethane	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	71-55-6	1,1,1-Trichloroethane	<1.40	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	71-43-2	Benzene	19.00	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	56-23-5	Carbon Tetrachloride	<1.20	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	110-82-7	Cyclohexane	<2.20	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	78-87-5	1,2-Dichloropropane	<1.70	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-27-4	Bromodichloromethane	<1.20	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	79-01-6	Trichloroethene	<1.40	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	123-91-1	1,4-Dioxane	<2.10	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	142-82-5	n-Heptane	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	10061-01-5	cis-1,3-Dichloropropene	<1.70	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	108-10-1	4-Methyl-2-pentanone	<1.85	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	10061-02-6	trans-1,3-Dichloropropene	<1.70	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	79-00-5	1,1-2-Trichloroethane	<1.40	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	108-88-3	Toluene	<2.00	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	591-78-6	2-Hexanone	<1.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	124-48-1	Dibromochloromethane	<0.90	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	106-93-4	1,2-Dibromoethane	<1.00	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	127-18-4	Tetrachloroethene	<1.10	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	108-90-7	Chlorobenzene	<1.70	ppmv	300

CLIENT_SAMPLE_NUMBER	DATE_COLLECTED	METHOD	CAS_NUMBER	COMPOUND_NAME	CONCENTRATION	UNITS	DILUTION_FACTOR
FL-2009 Inlet	4/2/2026	TO15	100-41-4	Ethylbenzene	<1.75	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	1330-20-7	m,p-Xylene	<1.75	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	75-25-2	Bromoform	<0.80	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	100-42-5	Styrene	<1.80	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	79-34-5	1,1,2,2-Tetrachloroethane	<1.10	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	95-47-6	o-Xylene	<1.80	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	100-44-7	Benzyl Chloride	<1.40	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	622-96-8	4-Ethyl Toluene	<1.60	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	108-67-8	1,3,5-Trimethyl Benzene	<1.60	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	95-63-6	1,2,4-Trimethyl Benzene	<1.60	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	541-73-1	1,3-Dichlorobenzene	<1.30	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	106-46-7	1,4-Dichlorobenzene	<1.30	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	95-50-1	1,2-Dichlorobenzene	<1.30	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	120-82-1	1,2,4-Trichlorobenzene	<4.10	ppmv	300
FL-2009 Inlet	4/2/2026	TO15	87-68-3	Hexachlorobutadiene	<2.90	ppmv	300

Appendix C

NORIT Activated Carbon – Vendor Documentation

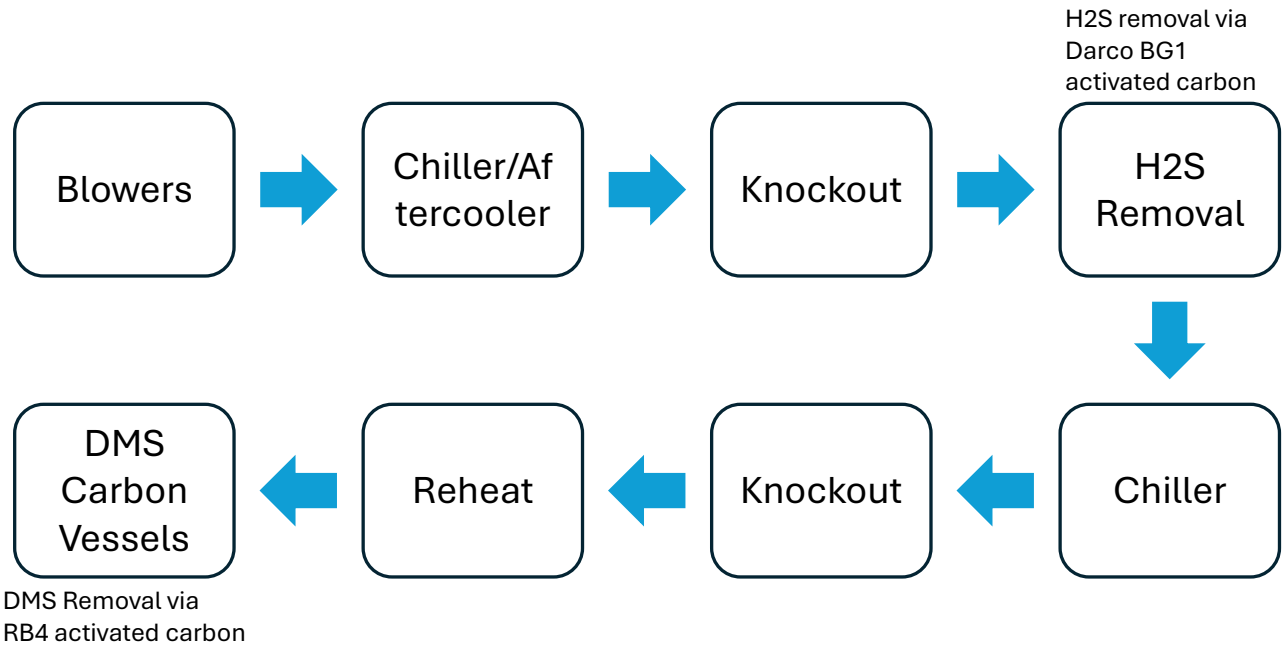
Norit Activated Carbon

H2S/DMS Removal

SCS Engineers Southern CA Project

August 2026

Process Flow



- For H2S removal via Darco BG1, gas RH% at 60-100%
- For VOC/DMS removal via Norit RB4, gas RH% at <50%

NORIT ACTIVATED CARBON

Norit Activated Carbon Pricing/Lead time

Darco BG1 (H2S removal)

- Packaging: 1000lb bulk bags
- Ships from: Texarkana, TX

- Price: $1.98/lb + freight
- Lead time:
  - First fill: 1-2 months
  - Changeouts: 2-3 weeks

Norit RB4 (VOC/DMS removal)

- Packaging: 450kg/992.08 lb bulk bags
- Ships from: Marshall, TX

- Price: $4.85/lb + freight
- Lead time:
  - First fill: 6 months
  - Changeouts: 2-3 week

NORIT ACTIVATED CARBON

H2S Management

Darco BG1 Activated Carbon for H2S Removal

- This summary shows a 2-vessel system, single train lead/lag. By doing so 4 of the 6-vessel limit can be allocated to VOC/DMS removal.
- 3,000 to 4,500 sq ft estimated footprint of this 2-vessel system
- There are numerous possible configuration/vessel options

Total Flowrate:	20,000 SCFM	Trains:	1
Train Flowrate:	20,000 SCFM	Total Vessels:	2

Gas Conditions and Assumptions:

Pressure:	10.0 psig	Relative Humidity:	90 %
Temperature:	80 F	Oxygen:	0.10 %

Target Contaminate: **Hydrogen Sulfide (H2S)**

Concentration of Contaminate: 175 ppm
Pounds of Sulfur (approximate): 452.1 pounds per day
165,006 pounds per year

Recommended Product: **DARCO BG1**

Media Vessels:

Number of Vessels: 2
Vessel Diamter: 26 ft
Vessel Cross-Section: 531 ft2

Media Bed Depth: 22.6 feet
Media Capacity per Bed (volume): 12,000 ft3
Recommended Media Capacity per Bed (weight): 300,000 pounds

Key Gas Properties:

Flow Velocity (feet per minute): 23.3 feet per minute
Empty Bed Contact Time (EBCT): 58.3 seconds
Estimated Pressure Drop (media only): 2.0 inches WC per ft of bed depth
Total Estimated Pressure Drop for Carbon (media only): 45.2 inches WC

Darco BG1 ($/lb): $ 1.96
Flowrate (scfm): 20,000 SCFM
Concentration of Target Contaminate: 175 ppm
Recommended Media Capacity per Bed (weight): 300,000 pounds

Site Annual Sulfur (lbs)	Loading (wt %)	Site Annual DARCO BG1 (lbs)	Vessel Media Bed Life (Days)	Site Annual Changeouts	$/lb H2S Removed
165,006	75%	220,008	498	0.7	$ 2.61
165,006	85%	194,125	564	0.6	$ 2.31
165,006	95%	173,691	630	0.6	$ 2.06

Disclaimer: The performance estimates provided are solely for informational purposes. Actual field performance is dependent on gas and operating conditions. These estimates do not constitute a warranty or performance guarantee.

NORIT ACTIVATED CARBON

VOC/DMS Management

- **Norit RB4 for VOC/DMS Management**
- Scenario 1: assumed that some type of additional VOC removal occurs ahead of this system, so that the carbon is left addressing primarily DMS

Total Flowrate:	20,000 SCFM	Trains:	2	
Train Flowrate:	10,000 SCFM			
Gas Conditions and Assumptions:				
Pressure:	8.0 psig	Relative Humidity:	50 %	(maximum limit)
Temperature:	100 F	Oxygen:	0 %	
Target Contaminate:	**DMS**			
Concentration of Contaminate:		500 ppm		
Est. Contaminant Load to Vessels:		1180 pounds per day		
Recommended Product:	**NORIT RB4**			
Vessel Properties:				
Number of Vessels: 4		Vessel Diameter: 26.0 ft		
Vessel Configuration: Single Vessel		Carbon Bed Depth: 23.9 ft		
Media Capacity per Bed (volume): 12,672 ft3		Bulk Bags (Qty): 350		
Media Capacity per Bed (weight): 347,213 pounds				

Performance Estimates:

Flow Velocity (feet per minute): 13 feet per minute
Empty Bed Contact Time (EBCT): 109 seconds
Estimated Time to Contaminant Breakthrough: 29 days
Total Estimated Pressure Drop for Carbon (media only): 6.0 inches WC
Est. Carbon Consumption Rate: 4,307,489 pounds per year

NORIT ACTIVATED CARBON

VOC/DMS Management

- **Norit RB4 for VOC/DMS Management**
- Scenario 2: No upstream removal of VOC's, the carbon beds are left to address the full contaminant load of the gas, including DMS.

Total Flowrate:	20,000 SCFM	Trains:	2
Train Flowrate:	10,000 SCFM		
Gas Conditions and Assumptions:			
Pressure:	8.0 psig	Relative Humidity:	<50%
Temperature:	100 F	Oxygen:	0 %
Target Contaminate:	**DMS**		
Concentration of Contaminate:		500 ppm	
Est. Contaminant Load to Vessels:		1180 pounds per day	
Recommended Product:	**NORIT RB4**		
Vessel Properties:			
Number of Vessels: 4		Vessel Diameter: 26.0 ft	
Vessel Configuration: Single Vessel		Carbon Bed Depth: 23.9 ft	
Media Capacity per Bed (volume): 12,672 ft3		Bulk Bags (Qty): 350	
Media Capacity per Bed (weight): 347,200 pounds			
Performance Estimates:			
Flow Velocity (feet per minute): 13 feet per minute			
Empty Bed Contact Time (EBCT): 109 seconds			
Estimated Time to Contaminant Breakthrough: 1 days			
Total Estimated Pressure Drop for Carbon (media only): 6.0 inches WC			
Est. Carbon Consumption Rate: 86,149,787 pounds per year			

NORIT ACTIVATED CARBON

Estimate Prepared by:
Omar Hasnain,
Sr. Applications Engineer
M +1-978-821-4529 E omar.hasnain@norit.com

July 31, 2026

Prepared For:	**SCS DMS - Exp. Chiquita - Ideal Case**	Revision: 1	
Total Flowrate:	15,000 SCFM	Trains:	6
Train Flowrate:	2,500 SCFM		

Gas Conditions and Assumptions:

Pressure:	- 1.3 psig	Relative Humidity:	50 % (maximum limit)
Temperature:	80 F	Oxygen:	0 %

Target Contaminate:	**DMS**	
Concentration of Contaminate:		500 ppm
Est. Contaminant Load to Vessels:		295 pounds per day

Recommended Product: **NORIT RB4**

Vessel Properties:

Number of Vessels: 6	Vessel Diameter: 12.0 ft
Vessel Configuration: Single Vessel	Carbon Bed Depth: 16.0 ft
Media Capacity per Bed (volume): 1,810 ft3	Bulk Bags (Qty): 50
Media Capacity per Bed (weight): 49,600 pounds	

Performance Estimates:

Flow Velocity (feet per minute): 25 feet per minute
Empty Bed Contact Time (EBCT): 38 seconds
Estimated Time to Contaminant Breakthrough: 17 days
Total Estimated Pressure Drop for Carbon (media only): 4.0 inches WC
Est. Carbon Consumption Rate: 1,076,872 pounds per year

Notes

1. Assumes moisture dehydration occurs upstream of ACT vessels
2. Assumes relative humidity does not exceed 50% RH
3. Assumes all VOCs are removed upstream of ACT vessels
4. DMS achieves maximum loading suggested under ideal conditions

Appendix D

UNICAT Catalyst Technologies – Vendor Documentation

UNICAT
CATALYST TECHNOLOGIES, LLC

COMMERCIAL PROPOSAL

SCS ENGINEERS

Catalyst & Process Technology Partner

INNOVATIVE | COLLABORATIVE | ROI-FOCUSED

WWW.UNICATCATALYST.COM

COMMERCIAL PROPOSAL

SCS Engineers

SR-101D, TSR-12SF & UNICARBON-HRU-CSP

August 21st, 2026

Unicat Reference No.: 3111

For any further information, please contact

Natalie Hamel

Regional Sales Manager, Americas

C: +1 (502) 860-1308

E: natalie.hamel@unicatcatalyst.com

Dear Chris,

We would like to thank you for inviting our company to bid on the catalyst requirements at SCS Engineers.

At UNICAT we are committed to delivering innovative catalyst solutions that enhance efficiency and drive performance. With decades of expertise and a strong commitment to quality, our products have been designed to optimize operational output while maintaining cost-effectiveness.

In line with your request on July 31st, please find the commercial proposal for the following products:

- **SR-101D:** Recommended replacement for the current activated carbon in the lead vessels. Based on two (2) vessels with a 20' ID and ~33.4' active bed height, plus 5% spillage, the required quantity is 22,050 ft^3, equivalent to 3,150 drums (7 ft^3/drum).

- **UNICARBON-HRU-CSP:** Recommended replacement for the current activated carbon in the top layer of the lag vessels. Based on two (2) vessels with a 20' ID and ~15.3' active bed height, plus 5% spillage, the required quantity is 10,045 ft^3, equivalent to 287 supersacks (35 ft^3/supersack).

- **TSR-12SF**: Recommended replacement for the current activated carbon in the bottom layer of the lag vessels. Based on two (2) vessels with a 20' ID and ~18.2' active bed height, plus 5% spillage, the required quantity is 11,998 ft^3, equivalent to 1714 drums (7 ft^3/drum).

This proposal outlines our customized pricing structure for SCS Engineers ensuring a competitive offer while fostering collaboration and innovation. By partnering with us, SCS Engineers will gain access to premium catalyst technology, expert support, and valuable insights for long-term success.

We look forward to working together and providing solutions tailored to your needs.

Yours sincerely,

Natalie Hamel
Regional Sales Manager, Americas
UNICAT Catalyst Technologies, LLC

c: +1 (502) 860-1308
e: natalie.hamel@unicatcatalyst.com
w: **www.unicatcatalyst.com**

Natalie Hamel

1. Commercial Proposal

Pricing Table

Product	Volume (ft^3)	Lead Time	Packaging	Unit Price ($/ft^3$)	Price ($)
UNICAT SR-101D-4E	22,050	20 weeks	3150 - Drums	$173.90	$3,834,495.00
UNICAT UNICARBON-HRU-CSP-4G	10,045	13 weeks	287 - Supersack	$136.62	$1,372,347.90
UNICAT TSR-12SF-4E	11,998	25 weeks	1714 - Drums	$274.26	$3,290,571.48
				Total	**$8,497,414.38**

Optional Support:

Product	Volume (ft^3)	Lead Time	Packaging	Unit Price ($/ft^3$)	Price ($)
Densimax-1/4”	1,330	13 weeks	38 - Supersack	$51.45	$68,428.50
Densimax-1/2”	665	13 weeks	19 - Supersack	$51.45	$34,214.25
Densimax-3/4”	5,600	13 weeks	160 - Supersack	$51.45	$288,120.00
				Total	**$390,762.75**

Terms

- **Lead time:** Initial fill: 25 weeks from purchase order (PO) confirmation. Refills: With a supply agreement in place, additional inventory can be stocked at a Unicat warehouse in the U.S., reducing overall lead times to 4-6 weeks.
- **Contingency:** The quoted quantities are as per vessel’s requirements, including 5% contingency as a precautionary measure to address any potential issues during the loading process, and rounded to the nearest whole container.
- **Payment Terms:** Net 30 days
- **Tariffs/Duties/Taxes:** The prices quoted are based on current tariffs, duties, and taxes. If there are any changes to these before the order is confirmed, the quoted prices may change, and this quotation will no longer be valid

- **Incoterms:** FCA – Alvin, TX.
- **Offer Validity:** The offer is valid for acceptance for 30 days from the date of this offer.
- **Packing:** 7 ft^3 drums. 35 ft^3 supersacks.
- **Return Policy**: UNICAT will authorize the return of any unopened product within 60 days of receipt of shipment at a 20% restocking fee subject to inspection upon arrival in our warehouse. All freight charges are at the expense of SCS Engineers.
- **Standard UNICAT per diem rate:** USD 2,000/shift (specialized engineer, for any extra service not included and or delays in loading outside of Unicat control).
- **End User Declaration:** An End User Declaration Form must be signed by the customer before any order can be acknowledged and processed. This form confirms that: (1) the products will be used solely for their original, declared scope by the customer and (2) the products will not be re-exported, resold, or diverted to other uses without prior written authorization from UNICAT.
- **Terms and Conditions:** UNICAT's standard terms and conditions of sale will apply, but we are amenable to review and agree reasonable mutual T&Cs with SCS Engineers.

This quote/proposal and fulfilment of any purchase order is subject to seller's ability to comply with all applicable UK, U.S., and other laws and regulations, including all prohibitions on exports or re-exports of the goods, services, or technology to countries or regions subject to UK, U.S., or other applicable sanctions or embargoes and all prohibitions on exports, re-exports, or in-country transfers to any person or entity listed on a UK, U.S., or other applicable restricted parties list or to any other restricted person or entity. If such laws change or otherwise make it unlawful to proceed, this quote/proposal becomes null and void. Acceptance of this quote/proposal obligates buyer to comply with all applicable laws, rules, and regulations in connection with the sale.

Confidentiality: The Content, Terms and Conditions of this Proposal are confidential between the parties – SCS Engineers & UNICAT and shall not be disclosed to anyone else. Any disclosure in violation of this section shall be deemed a material breach.

2. General Information about UNICAT Catalyst Technologies

Company Overview

UNICAT Catalyst Technologies, LLC is an innovative catalyst and process technology partner that collaborates with businesses to find effective solutions to increase efficiency and sustainability. Our technical expertise is demonstrated through high-quality, award-winning solutions and continuous investment in product development.

Global Presence

Headquartered in the United States, and manufacturing in USA, UK, Vietnam, and China. UNICAT operates with a global footprint, serving clients across the world. Our regional teams provide localized support and technical expertise to ensure seamless integration and performance of our catalyst solutions.

Core Products

- Syngas Production Catalysts – Full range of catalysts for syngas production using Steam Reforming or Gasification.
- Purification Catalysts – The broadest range of purification catalyst products available today is driven by an innovative approach.
- Hydroprocessing Applications – key focus on optimized bed grading and Purification Guard Technologies.
- Advanced Top Grading Systems – AFS technology.
- Specialty Markets – SPA catalysts, Bender Catalysts, etc.

Mission Statement

Proactively partner customers in achieving their goals (efficiency, profit, sustainability) by understanding their problems and needs and innovating solutions.

Vision

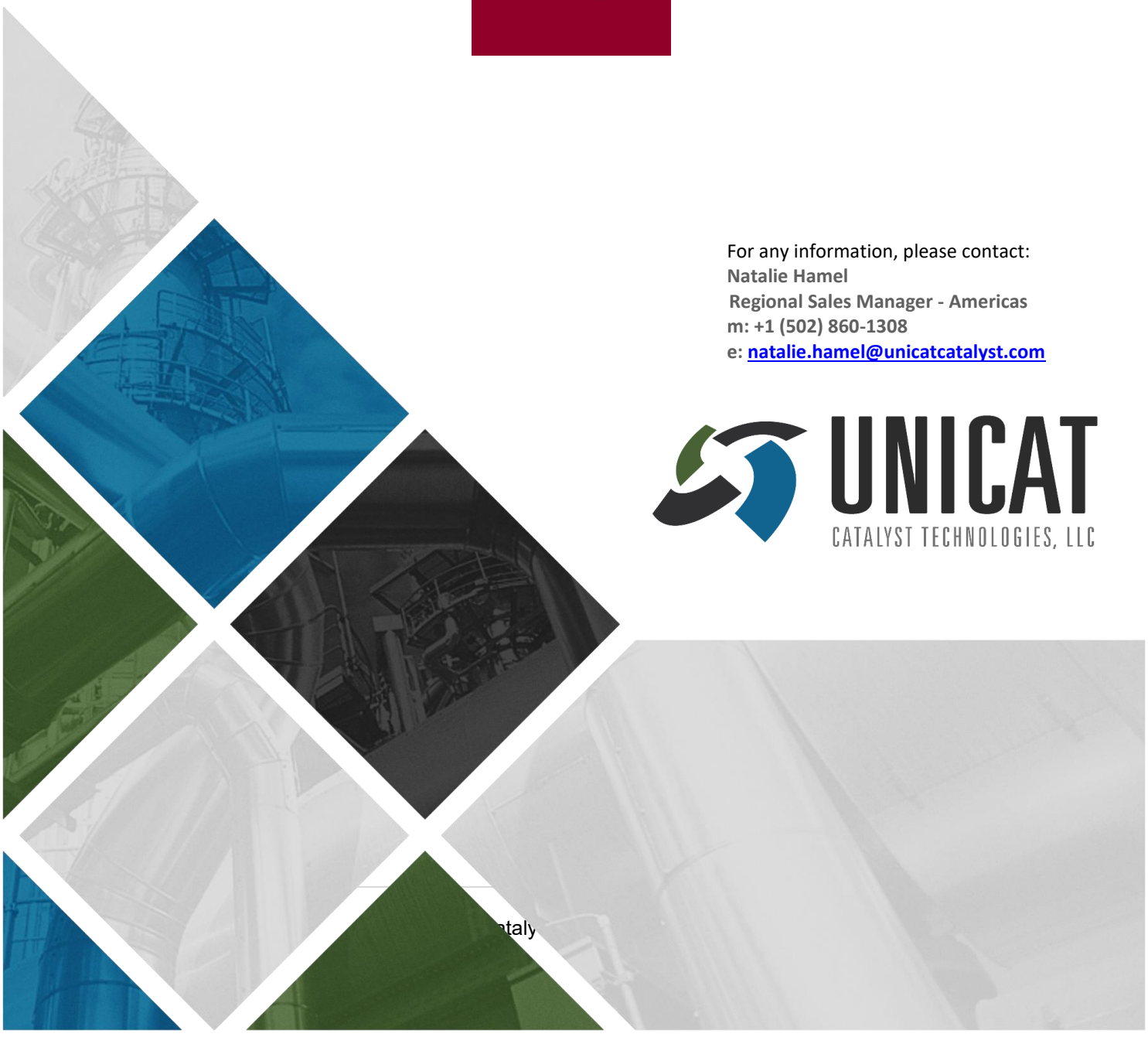
Optimizing performance through strategic partnerships with cutting-edge catalyst and process technology:

- Innovation.
- Flexible Manufacturing.
- Supply Chain Stability and Broad Product Range.

UNICAT Catalyst Technologies, LLC
5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

SCS Engineers

Sulfur Removal from Landfill Gas
Technical Proposal



For any information, please contact:
Natalie Hamel
Regional Sales Manager - Americas
m: +1 (502) 860-1308
e: natalie.hamel@unicatcatalyst.com

UNICAT Catalyst Technologies, LLC
5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

SCS Engineers

August 14, 2026

Attn: Chris Woloszyn, PE
E-Mail: cwoloszyn@scsengineers.com
Subject: H2S-DMS Treatment

Chris,

We would like to thank you for inviting UNICAT to bid for the SCS Landfill gas sulfur removal absorbent supply. We appreciate your consideration and welcome any follow-up questions.

UNICAT specializes in the manufacturing and application of a wide variety of sulfur removal catalysts and technologies for a broad spectrum of industries including refining, petrochemical, gas processing/production, and syngas production. This is important because it allows us to make recommendations on what is best for your specific application, not just a selection of variations of only one product type. We have technically evaluated the feed stream supplying the pretreatment unit and appreciate your consideration of the proposed solution.

Our proposed solution includes:

A new multi-bed approach including an iron oxide adsorbent to remove H_2S, a coconut carbon pretreatment step to remove VOC compounds, and UNICAT's polishing absorbent TSR-12SF to remove DMS:

Sulfur Removal Beds:	**UNICAT SR-101D-4E**
	UNICAT UNICARBON-HRU-CSP-4G
	UNICAT TSR-12SF-4E

A 5% contingency is recommended for all products and is included in the commercial quote below.

We do remain at your full disposal for any further information or clarification.

Yours sincerely,

Natalie Hamel

Natalie Hamel
Regional Sales Manager, Americas
UNICAT Catalyst Technologies, LLC
c: +1 (502) 860-1308
e: natalie.hamel@unicatcatalyst.com
w: **www.unicatcatalyst.com**

UNICAT Catalyst Technologies, LLC
5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

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5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

1. General information about UNICAT Catalyst and Technologies

UNICAT is a privately-owned company headquartered in Houston, Texas, USA. Since our founding in 2000, we have specialized in delivering high-performance catalyst products and services to the refining, petrochemical, and gas processing industries.

Today, UNICAT is a globally recognized supplier of catalysts and adsorbents, with deep expertise across the following key application areas:

- **SYNGAS** Products for modern syngas plants include absorbents and catalysts for hydrogen, methanol, ammonia, town gas, and coal gasification.
- **PSA** We use premium-range adsorbents and a deep technical understanding of engineering PSA systems to lead our customers to the best PSA performance possible.
- **AFS** (Advanced Filtration System) represents today's most advanced and comprehensive line of catalyst bed grading products.
- **POLYCAT** is a robust, solid phosphoric acid catalyst portfolio for multiple SPA polymerisation reactors (chamber and tubular) applications.
- **PURIFICATION** We offer Purification catalysts and adsorbents to meet customers' specific needs. Our products can focus on and remove Sulphur (All Types), Silicon, Arsine and Phosphate, Chloride and halogen, Mercury, Oxygen, and Reducing Gases.

With thousands of industrial references worldwide, UNICAT has established a strong track record across diverse application domains. We offer global sales and service support, with production facilities strategically located in China, the UK, the USA, India, and Vietnam—each equipped with associated storage facilities to ensure efficient supply chain operations.

Research and development are central to our innovation strategy, with core R&D operations based in Houston and supported by teams in the UK and at each production site.

UNICAT is committed to the highest standards of product quality. In addition to ISO protocols, every production lot undergoes rigorous quality control and verification against agreed specifications, including third-party testing to ensure consistency and reliability.

UNICAT Catalyst Technologies, LLC
5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

2. Technical Background

SCS Engineers is evaluating treatment alternatives for hydrogen sulfide (H_2S) and dimethyl sulfide (DMS) removal from landfill gas (LFG) at a client site located on the west coast, situated on the vacuum side of the well field. The site currently operates a dry solid scavenger system for H_2S treatment. Based on discussions with multiple vendors, effective treatment of DMS and H_2S is expected to require separate treatment stages rather than a single combined media system. Process conditions and gas compositions for the feed cases are shown in Table 1 below.

Table 1. Process Conditions and Gas Composition

Parameter	Current Case	Future Case
Pressure, psig	-2.0	-2.0
Temperature, °F	90 - 135	90 - 135
Flowrate, scfm	15,000	20,000
Relative humidity, RH	80%	80%

Gas Composition

Component	Design Case, %-v
N_2	45
CO_2	22
O_2	2.5 - 3.9
CH_4	30
Total	**100**

Contaminants

Contaminant	Units	Design	Maximum
DMS	ppmv	232	1,000
H_2S	ppmv	175	200
TOC	ppmv	208	208

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The function of the adsorbent bed(s) is to reduce sulfur below the air permit specification shown in Table 2.

Table 2. Required Purity for Treated Gas

(Product Specification – Effluent Requirement)

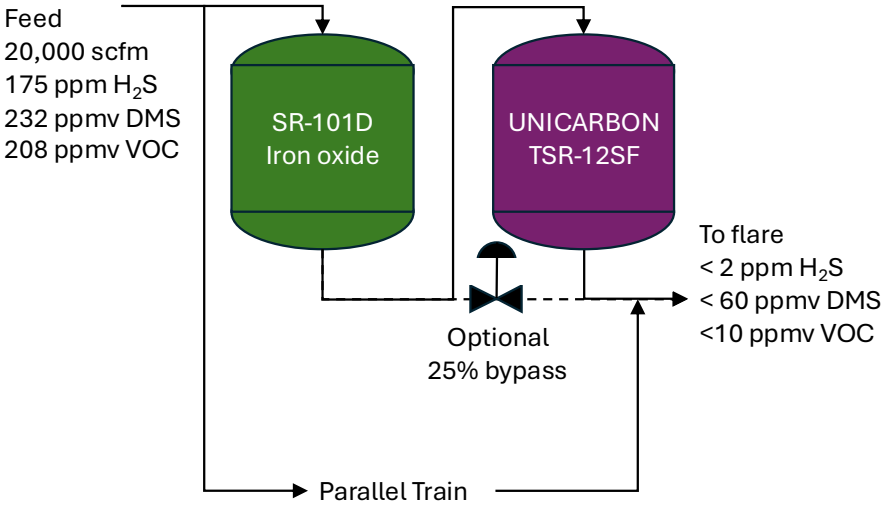
Component	**Composition**
Total S	< 60 ppmv

The current system consists of 4 vessels, with an option to expand to 6, each sized approximately 144 in x 180 in. The existing vessels are currently fiberglass but can be upgraded to stainless steel. Existing media (activated carbon) is undergoing replacement approximately every 4–6 weeks.
Site constraints include limited real estate due to the mountainous terrain. Some LFG flows are currently sent to flare due to questionable gas quality; other thermal oxidizer (TOX) units on-site are handling gas of worse quality, and these flows are expected to eventually be routed to the treatment system under evaluation.

As requested by SCS Engineers, we have provided the overall performance estimates for the Sulfur Removal beds under the current operating conditions. This technical proposal has been developed based on the data and documentation provided in the email exchange and telecon from July 2026.

3. Technical Proposal – H_2S and DMS removal

The scope of supply is to remove H_2S and DMS from the feed stream. However, the feed gas contains a significant concentration of oxygen-containing VOCs, which can compete with sulfur species for active adsorption sites and reduce the effective life of the adsorbents. Based on UNICAT technical review, VOCs are not expected to be removed in the upstream iron oxide SR-101D bed and should be assumed to pass through to the downstream carbon layer. A sequential sorbent configuration is recommended.



The sorbent is housed in two parallel trains containing two vessels each. Within each train, the H_2S removal adsorbent SR-101D-4E is installed first in a single vessel operating in a downflow configuration. The vessel contains 10,500 ft³ of sorbent and is designed to reduce H_2S in the feed stream from an average of 175 ppmv to < 2 ppmv. The expected service life is approximately 40 months of continuous operation before replacement. Please note, the relative humidity of the feed into the SR-101D vessel must be saturated and may require water injection to achieve this condition. Condensate management should also be considered in the vessel design (e.g., a separator, high efficiency demister pad, and automatic drains). The expected temperature rise given the inlet oxygen concentration of 2.5 - 3.9%-v is minimal and is not expected to exceed 20°F. However, oxygen to the bed must **always** be present. If for some reason, oxygen levels drop off temporarily, a build-up of FeS will occur, and this will react with the oxygen when it comes back, creating a very hot exotherm. The vessel should be insulated to ensure there is less than a 5°F temperature drop in gas temperature in the coldest environment. Please note, the vessel size is dictated by required contact time, not uptake capacity.

The second vessel in series contains two layers beginning with a 4,788 ft³ layer of sacrificial hydrocarbon removal adsorbent, UNICARBON-HRU-CSP, designed to reduce VOCs in the feed stream from 208 ppmv to <10 ppmv. The purpose of this layer is to remove as many reactive hydrocarbon species as possible prior to entering the targeted DMS-removal layer to prevent competition and premature deactivation. Because there is a spectrum of oxygenated contaminants, this bed will break through “chromatographically” as stronger adsorbates displace weaker ones at

UNICAT Catalyst Technologies, LLC
5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

the exit end of the bed. It is recommended to periodically monitor TOC speciation at the exit of the system to ensure that the changeout frequency is appropriate.

The second layer consists of 5,712 ft^3 of TSR-12SF to remove DMS from the feed stream. An optional 25% bypass may be used to treat only the fraction of the feed needed to meet the outlet specification of < 60 ppmv total sulfur, extending bed life. Sulfur monitoring is recommended at the outlet of each train. The expected service life for this vessel is approximately 1–2 months of continuous operation.

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5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

Proposed Sorbent for H_2S Removal: UNICAT SR-101D



UNICAT's SR-101D is the next generation of iron-based hydrogen sulfide removal absorbent. SR-101D is a blend of iron oxides and promotors with a proprietary binder for the removal of hydrogen sulfide from natural gas, wet off-gas, air, or landfill gas. SR-101D is supplied in extrudate form.

Technical Information		
Composition	Fe_2O_3	
Product	2E	4E
Shape	Extrudate	
Size (mm)	2.5	4
Loading Density kg/m^3 lbs/ft^3	 900 56	
Radial crush strength	≥7.0 N / mm ≥15 lb_f / mm	

UNICAT Catalyst Technologies, LLC
5918 S. Highway 35
Alvin, TX 77511
USA
O: 281.331.2231
WWW.UNICATCATALYST.COM

Proposed Sorbent for VOC Removal: UNICARBON HRU-CSP



UNICAT's UNICARBON-HRU-CSP is an activated carbon manufactured from selected-grade coconut shells and steam-activated at high temperature for use in vapor- and liquid-phase applications. The carbon exhibits a highly microporous structure and excellent mechanical hardness. UNICARBON-HRU-CSP provides strong performance in the removal of light hydrocarbons (C_1–C_4) and bulk CO_2 in hydrogen purification pressure swing adsorption (H_2 PSA) applications. Coconut-shell-based activated carbons are widely used in adsorption service due to their high microporosity, superior hardness, and low attrition. The product is particularly effective for removing weakly adsorbed compounds and for reducing emissions to trace concentration levels.

Technical Information		
Composition	Activated Carbon (coconut-shell based)	
Product	4G	6G
Shape	Granular	
Size (mm)	4x8 Mesh	6x12 Mesh
Sock Loaded Density kg/m^3 lbs/ft^3	 495 31.0	 510 32.0
Dense Loading Density (estimate) kg/m^3 lbs/ft^3	 594 37.1	 612 38.2
Ash (wt %)	< 3	<4

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5918 S. Highway 35
Alvin, TX 77511
USA
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Proposed Sorbent for DMS Removal: UNICAT TSR-12SF



UNICAT's TSR-12SF is a specialty bi-metal promoted sulfur absorbent engineered for the removal of trace H_2S, COS, and light organic sulfur species. Designed to meet the most stringent outlet sulfur specifications, TSR-12SF performs effectively in both gas and liquid-phase applications at ambient temperature. It is supplied in extrudate form for ease of use and consistent performance.

Technical Information		
Composition	Activated Carbon, CuO, FeO_3	
Product	3E	4E
Shape	Extrudate	
Size (mm)	3	4
Loading Density kg/m^3 lbs/ft^3	 560 35	
Radial crush strength	> 1 kg_f / mm > 2.2 lb_f / mm	

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Proposed Support Media: UNICAT Densimax



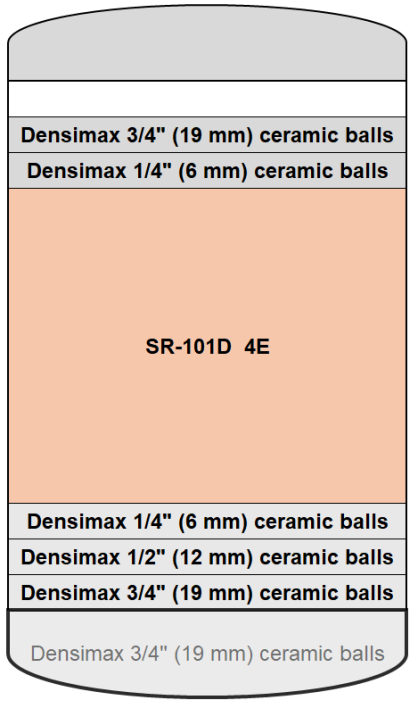
UNICAT's **Densimax** ceramic support series are inert support balls for general purpose grading applications in the top and bottom of reactor vessels at refineries, chemical facilities, and SynGas plants. Densimax is available in six standard sizes with specialty sizes produced upon request. Densimax has high crush strength due to its chemistry and its uniform spherical shape which permits a high stress distribution.

Technical Information						
Product Name		1/8"	1/4"	1/2"	3/4"	1"
Diameter	mm (±0.5)	3	6	12	19	25
Density	kg/m^3 (±5%)	1375	1375	1375	1375	1375
Density	lb/ft^3 (±5%)	85.8	85.8	85.8	85.8	85.8
Water Absorption	%	<1	<1	<1	<1	<1
Nominal Surface Area	m2/g	≥0.02	≥0.02	≥0.02	≥0.02	≥0.02
Crush Strength	kg-f	≥50	≥80	≥100	≥300	≥300

Composition [wt%]							
Al_2O_3	SiO_2	K_2O	Fe_2O_3	Na_2O	MgO	TiO_2	CaO
≥17	≥72	≤4	≤1.5	≤1.0	≤0.5	≤0.5	≤0.5

Loading Diagrams: H_2S Removal Bed

Vessel Tag No.H2S Removal
Flow direction:Downflow
Loading Method:Sock
Bed Int. Dia.= 20 ft

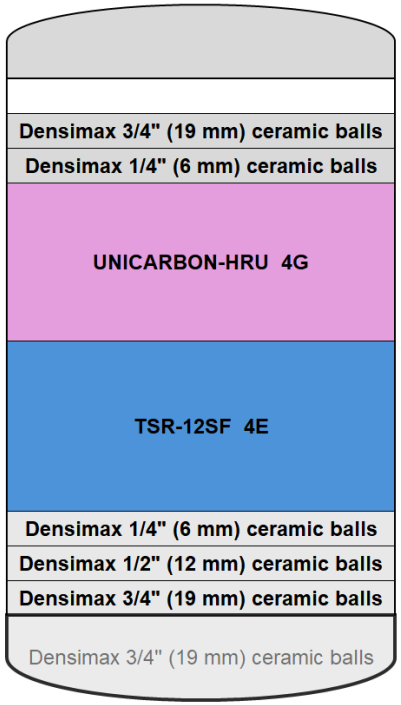


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Loaded Height	Catalyst/Absorbent/Adsorbent	Volume	Typical density	Loaded weight
in		*ft3*	*lb/ft3*	*lb*
6	Densimax 3/4" (19 mm) ceramic balls	157	86	13,483
6	Densimax 1/4" (6 mm) ceramic balls	157	86	13,483
401.08	SR-101D 4E	10500	56	589,958
6	Densimax 1/4" (6 mm) ceramic balls	157	86	13,483
6	Densimax 1/2" (12 mm) ceramic balls	157	86	13,483
4	Densimax 3/4" (19 mm) ceramic balls	105	86	8,989
Bottom of Head	Densimax 3/4" (19 mm) ceramic balls	1047	86	89,890

Loading Diagrams: DMS Removal Bed

Vessel Tag No.DMS Removal
Flow direction:Downflow
Loading Method:Sock
Bed Int. Dia.= 20 ft



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6	Densimax 3/4" (19 mm) ceramic balls	157	86	13,483
6	Densimax 1/4" (6 mm) ceramic balls	157	86	13,483
183	UNICARBON-HRU 4G	4788	30	143,484
218	TSR-12SF 4E	5712	35	201,470
6	Densimax 1/4" (6 mm) ceramic balls	157	86	13,483
6	Densimax 1/2" (12 mm) ceramic balls	157	86	13,483
4	Densimax 3/4" (19 mm) ceramic balls	105	86	8,989
Bottom of Head	Densimax 3/4" (19 mm) ceramic balls	1047	86	89,890

Performance Projections

We have made performance predictions based on the Design Case in Table 1.

The expected performance of sorbents is summarized below in Table 3:

Table 3. Performance summary

Variable	Unit	**Bed** 1 **SR-101D** **H_2S Removal**	**Bed** 2 Layer 1 **UNICARBON** **VOC Removal**	**Bed** 2 Layer 2 **TSR-12SF** **DMS Removal**
H_2S (outlet)	ppmv	< 2	<2	< 2
DMS (outlet)	ppmv	232	232	< 60
Capacity	%-w	35% H_2S	11% VOCs	3% DMS
Vessels		2	2	
Sorbent Volume	ft^3/vessel	10,500	4,788	5,712
Service life	months	40	1-2	1-2
Pressure drop SOR	psi	1.36	0.25	0.10
Minimum L/D	L/D	1.5	1.5	1.5
Temperature range	°F	Ambient – 200	Ambient – 175	

The proposed layered treatment approach is designed to achieve the required outlet sulfur specification while providing dedicated removal capacity for H_2S and DMS. The oxygenated VOC constituents are not expected to be removed in the upstream iron oxide SR-101D bed and should be assumed to pass through that vessel. VOC removal is assigned to the downstream UNICARBON-HRU-CSP layer, which protects the TSR-12SF DMS-removal layer from competitive adsorption and premature deactivation. Actual operating life will depend on feed composition variability, moisture control, flow distribution, and routine monitoring of sulfur and TOC breakthrough. UNICAT recommends continued field sampling and operating data review to confirm changeout timing and optimize long-term system performance.

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4. Technical Support

Below is listed the technical support that UNICAT can provide:

- Assistance, remote and on-site, for loading, start-up, and process troubleshooting as required.
- In case of emergency, UNICAT Catalyst personnel can provide immediate assistance by telephone or e-mail.
- UNICAT will review and provide input on start-up and shutdown procedures required for catalyst change-out.

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5. Terms and Conditions

UNICAT
Terms and Conditions of Sale
These terms and conditions of sale ("Terms") and the accompanying quotation or order acknowledgement ("Quotation" collectively with Terms, this “Agreement”) are the only terms that govern the sale of the goods identified in the Quotation ("Goods") by Unicat Catalyst Technologies, LLC ("Seller") to the buyer named therein ("Buyer"). Seller and Buyer may each be referred to as a "Party" or collectively as the "Parties." This Agreement supersedes all prior or contemporaneous understandings, agreements, negotiations, representations and warranties, and communications, both written and oral. Buyer’s issuance of a purchase order in response to Seller’s Quotation shall conclusively evidence Buyer's unconditional acceptance of these Terms, and Seller hereby rejects and shall not be bound by any terms or conditions in Buyer’s purchase order or other written communications that differ from, add to, or modify these Terms.

1. Delivery.

1.1. The Goods will be delivered within a reasonable time after the receipt of Buyer's purchase order, subject to availability of the Goods. Delivery dates given by Seller are estimates only and are subject to shipping variations and requirements. Time shall not be of the essence, and Buyer cannot reject the Goods or terminate the Agreement due to delivery delays. This condition remains in effect regardless of any notices served.

1.2. Unless otherwise agreed in writing by the Parties, Seller shall deliver the Goods FCA (Incoterms 2020) Alvin, TX using Seller's standard methods for packaging and shipping such Goods.

1.3. Seller may, in its sole discretion, without liability or penalty, make partial shipments of Goods to Buyer. Each shipment will constitute a separate sale, and Buyer shall pay for the units shipped whether such shipment is in whole or partial fulfillment of Buyer's purchase order.

1.4. If Seller requests the return of pallets or special packaging, Buyer must return them in good condition within 30 days of receipt at Buyer’s expense, or Seller will charge Buyer for their cost.

2. Acceptance of Order. Seller's acceptance of a purchase order shall be effective only where such acceptance is in writing and signed by an authorized representative of the Seller. A Quotation does not constitute an offer and Seller reserves the right to withdraw or revise a Quotation at any time before it accepts a purchase order.

3. Buyer Cancellation. In the event that Buyer cancels all or any portion of an accepted purchase order, Buyer shall reimburse Seller for all reasonable costs and expenses incurred by Seller or on Seller's behalf in connection with the cancelled order up to the date of cancellation. Such costs and expenses shall include, but are not limited to: (a) The cost of raw materials procured for the order; (b) Manufacturing costs incurred to date; (c) Labor costs directly attributable to the order; (d) Any non-cancellable commitments made by Seller to its suppliers or subcontractors in furtherance of the order; and (e) Any other direct costs reasonably incurred by Seller in reliance on the purchase order. Upon Buyer's request and at Buyer's expense, Seller shall deliver to Buyer any partially manufactured goods related to the cancelled order, provided that such delivery does not violate any applicable laws, regulations, or Seller's contractual obligations to third parties.

4. Safety Documentation. Seller maintains product literature and safety information detailing the necessary conditions for safe and proper use of the Goods. If Buyer does not already possess this safety literature or requires additional information or advice regarding the safe use of the Goods, Buyer should contact Seller's customer support department. Seller may periodically update safety information. Buyer is encouraged to check for the most current safety information before each use of the Goods.

5. Title and Risk of Loss. Risk of loss passes to Buyer upon delivery of Goods to the carrier. Seller shall not be liable for any loss of or damage to material in transit. Title to the Goods shall remain with Seller until Seller has received full payment of the purchase price. As collateral security for the payment of the purchase price of the Goods, Buyer hereby grants to Seller a lien on and security interest in and to all of the right, title, and interest of Buyer in, to, and under the Goods, wherever located, and whether now existing or hereafter arising or acquired from time to time, and in all accessions thereto and replacements or modifications thereof, as well as all proceeds (including insurance proceeds) of the foregoing. The security interest granted under this provision constitutes a purchase money security interest under the Texas Uniform Commercial Code. Upon receipt of full payment, Seller shall release its security interest, and title shall automatically pass to Buyer.

6. Amendment and Modification. These Terms may only be amended or modified in a writing which specifically states that it amends these Terms and is signed by an authorized representative of each Party.

7. Payment Terms.

7.1. Invoicing and Payment. Buyer shall pay Seller all invoiced amounts due within 7 days after the date of Seller's invoice. All payments hereunder shall be in U.S. dollars. Seller reserves the right to require pre-payment in its sole discretion.

7.2. Late Payment. Buyer shall pay interest on all delinquent payments at the lesser of the rate of 1.5% per month or the highest rate permissible under applicable law. Buyer shall reimburse Seller for all costs incurred in collecting any delinquent payments, including, without limitation, attorneys' fees. In addition to all other remedies available under this Agreement or at law (which Seller does not waive by the exercise of any rights hereunder), Seller shall be entitled to suspend the delivery of any Goods if Buyer fails to pay any amounts when due hereunder and such failure continues for 30 days following written notice thereof.

7.3. No Setoff. Buyer shall not withhold payment of any amounts due and payable by reason of any set-off of any claim or dispute with Seller, whether relating to Seller's breach, bankruptcy, or otherwise.

7.4. Taxes. All prices are exclusive of all sales, use, and excise taxes, and any other similar taxes, duties, and charges of any kind imposed by any governmental authority on any amounts payable by Buyer. Buyer shall be responsible for all such charges, costs, and taxes; provided, that, Buyer shall not be responsible for any taxes imposed on, or with respect to, Seller's income, revenues, gross receipts, personnel, or real or personal property or other assets.

8. Acceptance. Buyer shall inspect the Goods upon receipt and will be deemed to have accepted them unless, within 14 days of receipt, Buyer notifies Seller in writing that the Goods do not conform to the Quotation. If Buyer fails to provide such notice within this period, the Goods will be conclusively deemed to conform to the Quotation in all respects, and Buyer shall be bound to accept and pay for them as agreed. Quality or dimensional defects in a single delivery do not entitle Buyer to cancel the remainder of the order specified in the Quotation.

9. Limited Warranty. The Seller warrants to Buyer that upon receipt the Goods will materially conform to Seller’s specifications set forth in the applicable Quotation (the “Specifications”). Seller can change and improve the Specifications provided they are of the same or better quality than that given in the Quotation. The warranties under this section do not apply where the Goods have been: (a) subjected to abuse, misuse, neglect, negligence, accident, abnormal physical stress or environmental conditions, use contrary to any instructions issued by Seller, or improper testing, installation, storage, handling, repair, or maintenance; (b) reconstructed or altered by anyone other than Seller or its authorized representative; or (c) used with any third-party product, or product that has not been previously approved in writing by Seller. Buyer assumes risk and liability for the results of the use of the Goods including use in accordance with Seller’s recommendations.

10. Exclusive Remedy. Buyer shall notify Seller, in writing, of any alleged warranty claim within 14 days from the date Buyer discovers, or upon reasonable inspection should have discovered, such alleged claim. Buyer shall ship the relevant Goods at its expense and risk of loss to Seller's facility located in Alvin, Texas for inspection and testing by Seller. If Seller's inspection and testing reveals, to Seller's satisfaction, that such Goods do not conform with the limited warranty set forth herein, Seller shall in its sole discretion, and at its expense either (a) replace such Goods, or (b) credit or refund the price of such Goods less any applicable discounts, rebates, or credits. THIS SECTION 10 SETS FORTH THE BUYER'S SOLE AND EXCLUSIVE REMEDY AND SELLER'S ENTIRE LIABILITY FOR ANY BREACH OF THE LIMITED WARRANTY SET FORTH IN SECTION 9.

11. WARRANTIES DISCLAIMER. EXCEPT FOR THE EXPRESS WARRANTIES SET FORTH IN SECTION 9, SELLER MAKES NO EXPRESS OR IMPLIED WARRANTY WHATSOEVER WITH RESPECT TO THE GOODS, INCLUDING ANY (A) WARRANTY OF MERCHANTABILITY; (B) WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE; OR (C) WARRANTY AGAINST INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF A THIRD PARTY; WHETHER ARISING BY LAW, COURSE OF DEALING, COURSE OF PERFORMANCE, USAGE OF TRADE, OR OTHERWISE. BUYER ACKNOWLEDGES THAT IT HAS NOT RELIED UPON ANY REPRESENTATION OR WARRANTY MADE BY SELLER, OR ANY OTHER INDIVIDUAL OR ENTITY ON SELLER'S BEHALF, EXCEPT AS SPECIFICALLY PROVIDED IN SECTION 9 OF THESE TERMS.

12. LIMITATION OF LIABILITY.

12.1. IN NO EVENT SHALL SELLER OR ANY OF ITS REPRESENTATIVES BE LIABLE FOR CONSEQUENTIAL, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, PUNITIVE, OR ENHANCED DAMAGES, LOST PROFITS OR REVENUES OR DIMINUTION IN VALUE, ARISING OUT OF OR RELATING TO THIS AGREEMENT, REGARDLESS OF (A) WHETHER SUCH DAMAGES WERE FORESEEABLE, (B) WHETHER SELLER WAS ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, AND (C) THE LEGAL OR EQUITABLE THEORY (CONTRACT, TORT, OR OTHERWISE) UPON WHICH THE CLAIM IS BASED.

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12.2. SELLER'S AGGREGATE LIABILITY ARISING OUT OF OR RELATED TO THIS AGREEMENT, WHETHER ARISING OUT OF OR RELATED TO BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE) OR OTHERWISE, SHALL NOT EXCEED THE TOTAL OF THE AMOUNTS PAID BY BUYER FOR SUCH ORDER.

12.3. BUYER ACKNOWLEDGES AND AGREES THAT THE PARTIES ENTERED INTO THE AGREEMENT IN RELIANCE UPON THE LIMITATIONS OF LIABILITY SET FORTH IN THIS SECTION 12, THAT THE SAME REFLECT AN ALLOCATION OF RISK BETWEEN THE PARTIES (INCLUDING THE RISK THAT A CONTRACT REMEDY MAY FAIL OF ITS ESSENTIAL PURPOSE AND CAUSE CONSEQUENTIAL LOSS), AND THAT THE SAME FORM AN ESSENTIAL BASIS OF THE BARGAIN BETWEEN THE PARTIES.

13. Legal Compliance. Buyer shall comply with all applicable laws, rules, and regulations in connection with this sale, and in particular all laws governing the import and export of goods, all trade sanctions, and all laws prohibiting bribery. Buyer acknowledges that goods supplied by Seller are subject to the export control and sanctions laws of the United States, United Kingdom, the country from which they are exported, and perhaps other countries as well. Buyer shall not export, reexport, sell, or otherwise transfer goods supplied by Seller without the required authorization. Buyer further represents that it is not listed on any of the various denied parties lists established by the U.S., the U.K. and the EU, or any other applicable jurisdiction, including without limitation, the U.S. Department of the Treasury's Specially Designated Nationals and Blocked Persons List, HM Treasury's Office of Financial Sanctions Implementation's Consolidated List or the EU Consolidated Sanctions List. Further, Buyer certifies that it is not owned in the aggregate, directly or indirectly, 50 percent or more, by any individual that is included on any of the various denied parties' lists described above.

14. Confidentiality. All non-public, confidential, or proprietary information of Seller, including but not limited to specifications, samples, designs, drawings, documents, data, business operations, customer lists, pricing, or discounts, disclosed by Seller to Buyer, whether disclosed orally or disclosed or accessed in written, electronic, or other form or media, and whether or not marked, designated, or otherwise identified as "confidential" in connection with this Agreement, shall be considered confidential, solely for the use of performing this Agreement, and may not be disclosed or copied unless authorized in advance by Seller in writing. Upon Seller's request, Buyer shall promptly return all documents and other materials received from Seller. Seller shall be entitled to injunctive relief for any violation of this Section. This Section does not apply to information that is: (a) in the public domain; (b) known to Buyer at the time of disclosure; or (c) rightfully obtained by Buyer on a non-confidential basis from a third party.

15. Intellectual Property. All intellectual property rights, including but not limited to patents, trademarks, copyrights, trade secrets, proprietary information, and other rights ("Intellectual Property Rights") in and to the Goods and any related documentation, software, or technology, are and shall remain the exclusive property of Seller or its licensors. The sale of Goods to Buyer does not constitute a transfer, assignment, or license of any Intellectual Property Rights to Buyer.

16. Force Majeure. Neither Party shall be liable or responsible to the other Party, nor be deemed to have defaulted under or breached this Agreement, for any failure or delay in fulfilling or performing any term of this Agreement (except for any obligations to make payments to the other Party hereunder), when and to the extent such failure or delay is caused by or results from acts beyond the impacted Party's ("Impacted Party") reasonable control, including, the following force majeure events ("Force Majeure Events"): (a) acts of God; (b) flood, fire, earthquake, epidemics, pandemics, or explosion; (c) war, invasion, hostilities (whether war is declared or not), terrorist threats or acts, riot or other civil unrest; (d) order or action by any governmental authority or requirements of law; (e) embargoes or blockades in effect on or after the date of this Agreement; (f) national or regional emergency; (g) strikes, delays by suppliers, accidents, lock outs, material shortages, damage to machines plant or stock, labor stoppages or slowdowns, or other industrial disturbances; (h) telecommunication breakdowns, power outages or shortages, lack of warehouse or storage space, inadequate transportation services, or inability or delay in obtaining supplies of adequate or suitable materials; and (i) other events beyond the reasonable control of the Impacted Party.

17. Assignment. Buyer's rights, interests, or obligations hereunder may not be assigned, transferred, or delegated by Buyer without the prior written consent of Seller. Any purported assignment or delegation in violation of this Section is null and void. No assignment or delegation relieves Buyer of any of its obligations under this Agreement.

18. Relationship of the Parties. The relationship between the Parties is that of independent contractors. Nothing contained in this Agreement shall be construed as creating any agency, partnership, joint venture, or other form of joint enterprise, employment, or fiduciary relationship between the parties, and neither Party shall have authority to contract for or bind the other Party in any manner whatsoever.

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19. No Third-Party Beneficiaries. This Agreement benefits solely the Parties to this Agreement. Nothing in this Agreement, express or implied, confers on any other person any legal or equitable right, benefit, or remedy of any nature whatsoever under or by reason of this Agreement.
20. Governing Law; Jurisdiction. This Agreement is governed by and construed in accordance with the laws of the State of Texas without giving effect to any conflict of laws provisions thereof. All legal proceedings shall be instituted in the state or federal courts of the State of Texas. Each Party irrevocably and unconditionally submits to the exclusive jurisdiction of such courts. The parties agree that the United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.
21. Attorney Fees. In the event that any Party institutes any legal suit, action, or proceeding, including arbitration, against the other Party arising out of or relating to this Agreement, the prevailing Party in the suit, action, or proceeding shall be entitled to receive, in addition to all other damages to which it may be entitled, the costs incurred by such Party in conducting the suit, action, or proceeding, including reasonable attorneys' fees and expenses and court costs.
22. Notices. All notices shall be in writing and addressed to the parties at the addresses set forth on the face of the Quotation or to such other address for either Party as that Party may designate by written notice. All notices must be delivered by nationally recognized overnight courier, or certified or registered mail (in each case, return receipt requested).
23. Severability. If any term or provision of this Agreement is determined to be invalid, illegal, or unenforceable in any jurisdiction, such invalidity, illegality, or unenforceability shall not affect any other term or provision of this Agreement or invalidate or render unenforceable such term or provision in any other jurisdiction.
24. Waiver. No waiver by Seller of any of the provisions of this Agreement is effective unless explicitly set forth in writing and signed by Seller. No failure to exercise, or delay in exercising, any right, remedy, power, or privilege arising from this Agreement by Seller operates or may be construed, as a waiver thereof. No single or partial exercise of any right, remedy, power, or privilege hereunder by Seller precludes any other or further exercise thereof or the exercise of any other right, remedy, power, or privilege by Seller.

UNICAT
Terms and Conditions of Sale

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   - 2.2. Unless otherwise agreed in writing by the Parties, Seller shall deliver the Goods FCA (Incoterms 2020) Alvin, TX using Seller's standard methods for packaging and shipping such Goods.
   - 2.3. Seller may, in its sole discretion, without liability or penalty, make partial shipments of Goods to Buyer. Each shipment will constitute a separate sale, and Buyer shall pay for the units shipped whether such shipment is in whole or partial fulfillment of Buyer's purchase order.
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7. **Amendment and Modification.** These Terms may only be amended or modified in a writing which specifically states that it amends these Terms and is signed by an authorized representative of each Party.
8. **Payment Terms.**
   - 8.1. **Invoicing and Payment.** Buyer shall pay Seller all invoiced amounts due within 30 days after the date of Seller's invoice. All payments hereunder shall be in U.S. dollars. Seller reserves the right to require pre-payment in its sole discretion.
   - 8.2. **Late Payment**. Buyer shall pay interest on all delinquent payments at the lesser of the rate of 1.5% per month or the highest rate permissible under applicable law. Buyer shall reimburse Seller for all costs incurred in collecting any delinquent payments, including, without limitation, attorneys' fees. In addition to all other remedies available under this Agreement or at law (which Seller does not waive by the exercise of any rights hereunder), Seller shall be entitled to suspend the delivery of any Goods if Buyer fails to pay any amounts when due hereunder and such failure continues for 30 days following written notice thereof.
   - 8.3. **No Setoff**. Buyer shall not withhold payment of any amounts due and payable by reason of any set-off of any claim or dispute with Seller, whether relating to Seller's breach, bankruptcy, or otherwise.
   - 8.4. **Taxes**. All prices are exclusive of all sales, use, and excise taxes, and any other similar taxes, duties, and charges of any kind imposed by any governmental authority on any amounts payable by Buyer, unless stated otherwise in writing. For the avoidance of doubt, any customs duties, tariffs, import fees, or retaliatory duties (including any new, increased, or reinterpreted measures) imposed or increased at any time, whether before or after acceptance of Quotation, order placement, shipment, delivery, or invoicing, shall be solely for Buyer's account and shall be charged to and payable by Buyer in addition to the invoiced price. Seller shall bear no obligation to absorb, rebate, credit, or otherwise compensate Buyer for any reduction, removal, or non-application of such duties or tariffs, and no price adjustment or refund shall be made once an order is accepted or invoiced. Buyer shall be responsible for all such charges, costs, and taxes; provided, that, Buyer shall not be responsible for any taxes imposed on, or with respect to, Seller's income, revenues, gross receipts, personnel, or real or personal property or other assets.
9. **Acceptance.** Buyer shall inspect the Goods upon receipt and will be deemed to have accepted them unless, within 14 days of receipt, Buyer notifies Seller in writing that the Goods do not conform to the Quotation. If Buyer fails to provide such notice within this period, the Goods will be conclusively deemed to conform to the Quotation in all respects, and Buyer shall be bound to accept and pay for them as agreed. Quality or dimensional defects in a single delivery do not entitle Buyer to cancel the remainder of the order specified in the Quotation.
10. **Limited Warranty.** The Seller warrants to Buyer that upon receipt the Goods will materially conform to Seller's specifications set forth in the applicable Quotation (the "**Specifications**"). Seller can change and improve the Specifications provided they are of the same or better quality than that given in the Quotation. The warranties under this section do not apply where the Goods have been: (a) subjected to abuse, misuse, neglect, negligence, accident, abnormal physical stress or environmental conditions, use contrary to any instructions issued by Seller, or improper testing, installation, storage, handling, repair, or maintenance; (b) reconstructed or altered by anyone other than Seller or its authorized representative; or (c) used with any third-party product, or product that has not been previously approved in writing by Seller. Buyer assumes risk and liability for the results of the use of the Goods including use in accordance with Seller's recommendations.
11. **Exclusive Remedy**. Buyer shall notify Seller, in writing, of any alleged warranty claim within 14 days from the date Buyer discovers, or upon reasonable inspection should have discovered, such alleged claim. Buyer shall ship the relevant Goods at its expense and risk of loss to Seller's facility located in Alvin, Texas for inspection and testing by Seller. If Seller's inspection and testing reveals, to Seller's satisfaction, that such Goods do not conform with the limited warranty set forth herein, Seller shall in its sole discretion, and at its expense either (a) replace such Goods, or (b) credit or refund the price of such Goods less any applicable discounts, rebates, or credits. THIS SECTION 10 SETS FORTH THE BUYER'S SOLE AND EXCLUSIVE REMEDY AND SELLER'S ENTIRE LIABILITY FOR ANY BREACH OF THE LIMITED WARRANTY SET FORTH IN SECTION 9.
12. **WARRANTIES DISCLAIMER. EXCEPT FOR THE EXPRESS WARRANTIES SET FORTH IN SECTION 9, SELLER MAKES NO EXPRESS OR IMPLIED WARRANTY WHATSOEVER WITH RESPECT TO THE GOODS, INCLUDING ANY (A) WARRANTY OF MERCHANTABILITY; (B) WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE; OR (C) WARRANTY AGAINST INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF A THIRD PARTY; WHETHER ARISING BY LAW, COURSE OF DEALING, COURSE OF PERFORMANCE, USAGE OF TRADE, OR OTHERWISE. BUYER ACKNOWLEDGES THAT IT HAS NOT RELIED UPON ANY REPRESENTATION OR WARRANTY MADE BY SELLER, OR ANY OTHER INDIVIDUAL OR ENTITY ON SELLER'S BEHALF, EXCEPT AS SPECIFICALLY PROVIDED IN SECTION 9 OF THESE TERMS.**
13. **LIMITATION OF LIABILITY.**
   - 13.1. **IN NO EVENT SHALL SELLER OR ANY OF ITS REPRESENTATIVES BE LIABLE FOR CONSEQUENTIAL, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, PUNITIVE, OR ENHANCED DAMAGES, LOST PROFITS OR REVENUES OR DIMINUTION IN VALUE, ARISING OUT OF OR RELATING TO THIS AGREEMENT, REGARDLESS OF (A) WHETHER SUCH**

DAMAGES WERE FORESEEABLE, (B) WHETHER SELLER WAS ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, AND (C) THE LEGAL OR EQUITABLE THEORY (CONTRACT, TORT, OR OTHERWISE) UPON WHICH THE CLAIM IS BASED.

13.2. **SELLER'S AGGREGATE LIABILITY ARISING OUT OF OR RELATED TO THIS AGREEMENT, WHETHER ARISING OUT OF OR RELATED TO BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE) OR OTHERWISE, SHALL NOT EXCEED THE TOTAL OF THE AMOUNTS PAID BY BUYER FOR SUCH ORDER.**

13.3. **BUYER ACKNOWLEDGES AND AGREES THAT THE PARTIES ENTERED INTO THE AGREEMENT IN RELIANCE UPON THE LIMITATIONS OF LIABILITY SET FORTH IN THIS SECTION 12, THAT THE SAME REFLECT AN ALLOCATION OF RISK BETWEEN THE PARTIES (INCLUDING THE RISK THAT A CONTRACT REMEDY MAY FAIL OF ITS ESSENTIAL PURPOSE AND CAUSE CONSEQUENTIAL LOSS), AND THAT THE SAME FORM AN ESSENTIAL BASIS OF THE BARGAIN BETWEEN THE PARTIES.**

14. **Legal Compliance.** Buyer shall comply with all applicable laws, rules, and regulations in connection with this sale, and in particular all laws governing the import and export of goods, all trade sanctions, and all laws prohibiting bribery. Buyer acknowledges that goods supplied by Seller are subject to the export control and sanctions laws of the United States, United Kingdom, the country from which they are exported, and perhaps other countries as well. Buyer shall not export, reexport, sell, or otherwise transfer goods supplied by Seller without the required authorization. Buyer further represents that it is not listed on any of the various denied parties lists established by the U.S., the U.K. and the EU, or any other applicable jurisdiction, including without limitation, the U.S. Department of the Treasury's Specially Designated Nationals and Blocked Persons List, HM Treasury's Office of Financial Sanctions Implementation's Consolidated List or the EU Consolidated Sanctions List. Further, Buyer certifies that it is not owned in the aggregate, directly or indirectly, 50 percent or more, by any individual that is included on any of the various denied parties' lists described above.

15. **Confidentiality.** All non-public, confidential, or proprietary information of Seller, including but not limited to specifications, samples, designs, drawings, documents, data, business operations, customer lists, pricing, or discounts, disclosed by Seller to Buyer, whether disclosed orally or disclosed or accessed in written, electronic, or other form or media, and whether or not marked, designated, or otherwise identified as "confidential" in connection with this Agreement, shall be considered confidential, solely for the use of performing this Agreement, and may not be disclosed or copied unless authorized in advance by Seller in writing. Upon Seller's request, Buyer shall promptly return all documents and other materials received from Seller. Seller shall be entitled to injunctive relief for any violation of this Section. This Section does not apply to information that is:
(a) in the public domain; (b) known to Buyer at the time of disclosure; or (c) rightfully obtained by Buyer on a non-confidential basis from a third party.

16. **Intellectual Property**. All intellectual property rights, including but not limited to patents, trademarks, copyrights, trade secrets, proprietary information, and other rights ("**Intellectual Property Rights**") in and to the Goods and any related documentation, software, or technology, are and shall remain the exclusive property of Seller or its licensors. The sale of Goods to Buyer does not constitute a transfer, assignment, or license of any Intellectual Property Rights to Buyer.

17. **Force Majeure.** Neither Party shall be liable or responsible to the other Party, nor be deemed to have defaulted under or breached this Agreement, for any failure or delay in fulfilling or performing any term of this Agreement (except for any obligations to make payments to the other Party hereunder), when and to the extent such failure or delay is caused by or results from acts beyond the impacted Party's ("**Impacted Party**") reasonable control, including, the following force majeure events ("**Force Majeure Events**"): (a) acts of God; (b) flood, fire, earthquake, epidemics, pandemics, or explosion; (c) war, invasion, hostilities (whether war is declared or not), terrorist threats or acts, riot or other civil unrest; (d) order or action by any governmental authority or requirements of law; (e) embargoes or blockades in effect on or after the date of this Agreement; (f) national or regional emergency; (g) strikes, delays by suppliers, accidents, lock outs, material shortages, damage to machines plant or stock, labor stoppages or slowdowns, or other industrial disturbances; (h) telecommunication breakdowns, power outages or shortages, lack of warehouse or storage space, inadequate transportation services, or inability or delay in obtaining supplies of adequate or suitable materials; and (i) other events beyond the reasonable control of the Impacted Party.

18. **Assignment.** Buyer's rights, interests, or obligations hereunder may not be assigned, transferred, or delegated by Buyer without the prior written consent of Seller. Any purported assignment or delegation in violation of this Section is null and void. No assignment or delegation relieves Buyer of any of its obligations under this Agreement.

19. **Relationship of the Parties.** The relationship between the Parties is that of independent contractors. Nothing contained in this Agreement shall be construed as creating any agency, partnership, joint venture, or other form of joint enterprise, employment, or fiduciary relationship between the parties, and neither Party shall have authority to contract for or bind the other Party in any manner whatsoever.

20. **No Third-Party Beneficiaries.** This Agreement benefits solely the Parties to this Agreement. Nothing in this Agreement, express or implied, confers on any other person any legal or equitable right, benefit, or remedy of any nature whatsoever under or by reason of this Agreement.

21. **Governing Law; Jurisdiction.** This Agreement is governed by and construed in accordance with the laws of the State of Texas without giving effect to any conflict of laws provisions thereof. All legal proceedings shall be instituted in the state or federal courts of the State of Texas. Each Party irrevocably and unconditionally submits to the exclusive jurisdiction of such courts. The parties agree that the United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

22. **Attorney Fees**. In the event that any Party institutes any legal suit, action, or proceeding, including arbitration, against the other Party arising out of or relating to this Agreement, the prevailing Party in the suit, action, or proceeding shall be entitled to receive, in addition to all other damages to which it may be entitled, the costs incurred by such Party in conducting the suit, action, or proceeding, including reasonable attorneys' fees and expenses and court costs.

23. **Notices.** All notices shall be in writing and addressed to the parties at the addresses set forth on the face of the Quotation or to such other address for either Party as that Party may designate by written notice. All notices must be delivered by nationally recognized overnight courier, or certified or registered mail (in each case, return receipt requested).

24. **Severability.** If any term or provision of this Agreement is determined to be invalid, illegal, or unenforceable in any jurisdiction, such invalidity, illegality, or unenforceability shall not affect any other term or provision of this Agreement or invalidate or render unenforceable such term or provision in any other jurisdiction.

25. **Waiver.** No waiver by Seller of any of the provisions of this Agreement is effective unless explicitly set forth in writing and signed by Seller. No failure to exercise, or delay in exercising, any right, remedy, power, or privilege arising from this Agreement by Seller operates or may be construed, as a waiver thereof. No single or partial exercise of any right, remedy, power, or privilege hereunder by Seller precludes any other or further exercise thereof or the exercise of any other right, remedy, power, or privilege by Seller.

Appendix E

Theia, LLC – Vendor Documentation

Matthew Keller
Project Professional
SCS ENGINEERS

Reference: H2S& DMS treatment System for a West Coast Landfill
Our reference: 72726GF1

We are pleased to provide the following budgetary estimate and preliminary proposal for the above referenced site.

Discussion: SCS Engineers is looking for a solution for this site to remove the majority of H2S and DMS from a large flow of landfill gas.

Inlet landfill gas flow rate = 15,000 to 20,000 CFM
Inlet landfill gas pressure = -70" WC (12.16 PSIA)
Inlet landfill gas temperature = 90-130 °F
Inlet landfill gas composition:

- CH4 = 30 %
- CO2 = 22%
- N2 = 45 %
- O2 = 3%

H2S Inlet: 150-200 ppmv
DMS Inlet 200-1000 ppmv

Required discharge: 80 ppmv total sulfur

Discussion: removal of H2S from Landfill Gas can be achieved using a number of technologies. Removing DMS is a bit more involved depending on what technology you utilize.

*NOTE: the gas can likely be treated to remove sufficient CO2 to allow the gas to be used for power generation or combustio*n

The two simplest technologies also represent the smallest capital costs.

- Activated carbon will remove both compounds with high efficiency. Capital cost would be roughly $ 300,000.00. Operating costs will be $ 3000-11,000 per day in media replacement cost (includes the replacement service).
  - Sourcing vapor phase carbon media in the US is the most expensive it has been in many years
  - While carbon is efficient on both, the high humidity in the gas will greatly reduce the efficiency of removal for DMS as it is adsorbed directly.
- Chemical scrubbing. Capital costs will be $ 600,000-800,000 with high chemical and water use.

Solution: the following system design is a combination of proven technologies assembled in a somewhat unique manner. That is, we have utilized each of these technologies in the past. We have included a number of stages in the design. It is entirely possible that not all of them will be required. We strongly recommend that some pilot testing be conducted should you decide to proceed/

Solution: TDM and its team offers a variety of solutions for removal and treatment of Hydrogen Sulfide (H2S) that is present in landfill and digester gas.

Discussion: The EOS system offers cost effective removal and treatment of Hydrogen Sulfide as well as other sulfide compounds. While this solution is a combination of proven technologies, the system itself has been only been tested in pilot tests to date.

Proposed Solution: TDM would like to offer the following proposed solution. One Eos multi-stage sulfide reduction system. System includes the following stages/components. The system is designed to treat the average flow and concentrations but will have the capacity to treat the maximum flow rate or the maximum contaminant loading.

Stage 1: LoCHem H_2S wet scrubbing System designed to treat 15,000 to 20,000 cfm of gas. System is designed to treat a steady flow of gas with some mild fluctuations. Larger fluctuations of the flow rate will be accommodated through simple manual adjustments to the system. System utilizes basic scrubber mechanics but operates very close to a 7.0 pH and uses the pH to solubilize the H2S only. It is not chemically oxidized.

- System generates a fine spray using a high velocity non-clog nozzle array.
- H2S is converted to S2 or SO4 using the Oxygenator nozzle. This unique technology utilizes ambient air to directly oxidize H2S.
- Any H2S which is converted to a water soluble version like HS- will be biologically oxidized later in the system.
- The oxidation occurs in a separate tank so that no air is introduced into the gas.
- Water is kept at a pH as close to 7.0 as possible using Icarus calcium media. This step ,minimizes the amount of calcium used to remove CO2. This media imparts calcium compounds into the water passing through it, providing the chemical properties and cost effectiveness of lime while providing the ease of use and automation characteristics of caustic while being safer and easier to handle than either.
- This process will include a prefilter and Mist eliminator on the discharged to remove any foreign matter as well as to reduce the also remove entrained water and return it to the sump.

Stage two: gas will enter multiple biotrickling filter units. These units utilize a high efficiency vertical media which maximizes contact area while minimizing any biofouling and reduces water use and pressure drop. The system will feature four(4) 12 foot diameter towers. Gas will enter the bottom and exit the top. Water will enter at the top.

Water will contain dissolved oxygen sufficient to allow the bacteria to fully oxidize the DMS that is solubilized in the water film on the media.

Water will drain into a secondary biological reactor which will allow for more time for the bacteria to break down any remaining DMS. This will be a high efficiency reactor which will be aerated but kept at an optimum oxygen content.

Stage Three: Biofilters: The systems will include three(3) rectangular biofilters. These are conventional rectangular modular units. Each unit will be 40 feet long x 8 feet wide with a 7-8 foot bed depth. Biofilters will be downflow models with removable covers and will utilize a specialized inorganic media. The biofilters will take in the off-gas directly from the biotrickling filters and will act as a polishing step.

Water: the system will include four(4) water stabilization and conditioning tanks. These tanks will serve as a reactors as well as to allow for the conditioning of the water for its task by removing some compounds and adding others.

Icarus: Two Polyethylene cone bottom mini-silos will holed sufficient media for 30 days of operations each. Once spent the media will be dumped and then will need to be replace by being loaded into the silos using supersacs.

Solids: there will be two sources of solids in the system.

- the Icarus system will generate spent media which will consist of inert substrate-mostly iron. The spent media will be dumped via gravity into dewatering boxes.
- Sludge from the reactions referenced above including sulfur, calcium sulfate, and dead bacteria, etc. These solids will be withdrawn and pumped into EZ Sludge dewatering boxes.
    - EZ Sludge system utilizes large geotextile sludge filters which are placed into specially designed tanks. Sludge is automatically pumped into the filters as needed. Water drains from the filter and is captured. The system automatically re-directs the solids as a filter gets filled.
    - The dewatering boxes are hauled off as is or the filters can be removed from the boxes.

Controls: the system will include a full set of controls including level control, pressure monitoring, pH, ORP and DO measurement and balancing. Control system will be powered by an Allen Bradley PLC with remote telemetry capability.

Packaging: the system will include multiple components which will need to be assembled in the field. It will be designed to “snap together” with interconnecting pieces being provided or designed such that it can be assembled quickly in the field.

- **System cost . . . $ 3,400,000.00 (estimated)**
- **Shipping to the site . . . $ 50,000.00**
- **Delivery 20-22 weeks from release for fabrication**

Pilot test . . . $ 75,000.00 (most of which would be recoverable with the purchase of the full scale system)

Operating costs, etc

- Water use – little or no water use. If the RH is 80% or above, the system will actually generate some water. The system will require an initial charge and may need clean water periodically but not on a daily basis and the extra water may be enough to prevent this from
- **Icarus media.** Roughly 1 to 1.5 tons per day of media which equates to $ ***100.00 to $ 150.00 a day.*** There will be 0.8 to 1.0 tons per day of inert material (spent media) which is DOT certified for use as fill or roadway material. It can be used for a number of purposes and is similar to gravel.
- **Sludge:** the system will generate 2-3 tons of dewatered sludge per day. Sludge will consist mostly of sulfur and calcium sulfate. This will likely qualify as a soil amendment. We place no commercial value on this as yet but it is possible that it would represent a zero cost disposal
    - Disposal will utilize Sludge filters which will need to be replaced once filled with up to 30 tons of solids(weight will be limited by the landfills ability to move the boxes. Based on 22 tons a sludge filter will consumed every 8 t***o 10 days at a cost of $ 950.00 each***
- **Power.** Estimated at 100-150 KVA.
- **Footprint** – estimated 50 x 120
- **Weather.** The system should sustain its own heat but can be sprayed or wrapped. This can be worked out along the way. A simple steel building would be worth considering. The system would likely only be in danger of freezing if it were not operating unless the temperatures are below freezing for sustained periods of time. Immersion heaters can also be placed into the tanks – this would cost $ 5-10,000.00 for he whole system

This is a **budgetary proposal** and as such no terms included. As referenced above, we strongly suggest that a pilot test be run before building a full scale system. If the need is pressing a pilot test can be run as the design and construction of the full system.

We will be forwarding a process diagram shortly. It needs to be cleaned up and I did not want to delay the proposal any further. If you have any questions please contact our office. Thank you for the opportunity to provide this proposal.

Sincerely,

George Federico

Sustainability Through Innovation
815 Lincoln Avenue, Unit 2, West Chester, PA 19380
www.TheiaLLC.com (888)330-2260

Friday, July 3, 2026

Matthew Keller
Project Professional
SCS ENGINEERS

Reference: DMS/H2S treatment for West Coast Landfill
Our reference: Solution presentation

We are pleased to provide the following technology recommendation for this project .

Application:

The following information has been provided to Theia:

Inlet landfill gas flow rate = 15,000 CFM average
= 20,000 CFM maximum sustained

Inlet landfill gas pressure = -
Inlet landfill gas temperature =
Inlet landfill gas composition:

- CH_4 = 30 mol%
- CO_2 = 22 mol%
- N_2 = 45 mol%
- O_2 = 3 mol%

DMS – 200 to 1000 ppmv
Average H2S Inlet: 150 ppmv.
Maximum Sustained H2S inlet: 200 ppmv
Required discharge. Unknown

Discussion: Theia and its team offers a variety of solutions for removal and treatment of Hydrogen Sulfide (H_2S) and other reduced sulfur compounds as well as VOC"s that is present in landfill and digester gas. We offer dry media which is a simple and reliable treatment method.

For higher H2S loading or when a combination of H2S and other compounds are present we offer a few different "wet" technologies which can be combined to present a cost effective, efficient treatment system.

Since DMS is the main concern, biological treatment would be the most appropriate. Additionally as H2S and DMS require different approaches from a biological treatment stand point, using more than one technology will be more effective

There is a misconception in industry that using multiple stages is more expensive and more complicated. The opposite is often true.

Because our approach utilizes biological oxidation to convert the sulfur compounds in the gas to non-gaseous forms of sulfur, wild fluctuations in these sulfur species can cause and issue for the system. We have mitigated any potential issues by utilizing a few different tools which work synergistically. Our basic approach will utilize very little in the way of chemicals

For this application, to best capture the DMS we will utilize a multi-step process.

- **Ultra high surface area contacting chamber** – this chamber utilizes a micro-droplet spray to create exceptionally high surface area of contact between gas and water
- **Oxygenator/Biotrickling filter** – this unit will biologically oxidize the H2S and some DMS. The H2S will be quickly converted to sulfur or sulfates
- **Biofilter** – inorganic long life media – this unit will do the majority of DMS oxidation
- **Process tank**. This tank will contain an active bioreactor which will handle some of the H2S as well as any DMS that the biofilter does not break down.
- **Oxygenator** system will directly oxidize H2S as well as saturating the water in the tank with dissolved oxygen . This water will be sent back to the biofilter and biotrickling units.
- **Icarus media.** This unique media is a recovered waste product with is made up of mostly of lime and iron. The media offers the cost effectiveness of lime without the complication and capital costs of silos and feeders. It operates automatically like a caustic feed system at a fraction of the operating costs

This system will generate calcium sulfate with some sulfur and has a sludge removal and dewatering process called EZ Sludge

An option is offered for a dry media polishing step. Again, as we do not have any actual discharge criteria, we can add a dry media polishing step if that is required.

This design offers a turnkey solution which is an assembly of proven technologies.

Additional steps: as discussed, this gas contains some potentially valuable components: methane, nitrogen, Carbon Dioxide. The carbon dioxide and Nitrogen can be separated making this a higher percentage methane which would be commercially usable. Alternatively, the system is capable of removing some, all, or almost none of the CO2 in the gas. This removal process would generate calcium carbonate which has commercial value

Gas Flow: Gas will enter the scrubber tower and travel downward into the contacting chamber. As it does it will come into contact with a fine spray of water. The water will have a pH of 7.5 to 8.0. Sulfides in the gas will be solubilized into the fine water spray and will be carried away with the scrubbing fluid as soluble sulfides.

Gas exiting the contacting chamber will enter a biotrickling filter. This step will remove the H2S and some of the DM. It will then enter a biofilter which will remove the remaining DMS and then pass through a moisture separator.

Gas will be drawn through the scrubber using a centrifugal blower. .

If needed, the gas will be sent through the Theia Dry media system. This system is a two-bed media vessel with an interconnecting manifold. The system will be bypassed during normal operations but can be brought online as needed. We are offering automated dampers to allow for this step to occur automatically.

Step 2: Water handling and treatment

The second main piece of the EOS system is the water processing system. The EOS system is designed to continuously recycle the process water such that little water is consumed in the process. This step greatly mitigates the need for fresh water while eliminating the creation of wastewater to be discharged. This step utilizes settling and filtration to remove any solids which have precipitated out of the water.

As needed, sludge is drawn out of the water treatment tank using heavy duty sludge pumps. The pumps are redundant each capable of handling the pumping requirements. Sludge will be sent to sludge dewatering system.

Solids Handling: The system will generate calcium sulfate volumes based on the volume of the incoming sulfide compounds. Much of the calcium sulfate will drop to the bottom of the cone in the tank and some will be removed by the filters. Solids from the tank will be removed using a sludge handling pump and sent to the solids handling system. The process tank has multiple connections for sludge withdraw which are piped into a manifold with valves. This design allows the operator to draw sludge from one area of the tank at a time or multiple ones. Additionally, the disc filters will also backwash to the solids handling system.

Solids are dewatered using Theia's EZ-Sludge system. This system utilizes gravity and time and does not require any labor or regular attention from the operator. Sludge will be 45-55% dry solids and can be and land applied or utilized as a soil amendment. { we have identified some potential outlets that can accept the sludge but we will need to test the sludge from the site and get them some to test. We should have outlets online by the time the system is operational.

Dry Media System:

We will provide a Theia Dry Media system which will be used as a ***polishing unit as well as a backup system for when the main system requires any maintenance.***

Media:

BG1 is a specially designed media that starts with a high grade activated carbon product that is specifically selected for its natural pore structure. The media is then extruded into a pellet and mixed with a proprietary catalyst to allow it to convert H2S to sulfur. The H_2S is not adsorbed but rather converted to non-reactive sulfur compounds which will not allow for the re-release of H_2S. H2S Rex will capture and hold 67% of its own weight in sulfides.

Theia Air Media does not clump or foul in standard operating conditions. This media also has excellent mechanical properties allowing higher superficial velocities, smaller vessels, and much lower pressure drop. Our media maintains this lower pressure drop through the balance of the process and, as such, the entire bed of media is utilized.

When spent, the media is considered usable as a soil amendment for non-food crop applications. The sulfur locked onto the media is a valuable resource for the long term health of many types of plants and trees.

If you have any questions or require any additional information, please contact our office. Thank you for the opportunity to provide this Solution .

Sincerely,

George Federico

ACG 275



Application: Sulfur removal from liquid hydrocarbon streams.

Description: Reduced and passivated nickel material for efficient removal of H_2S, mercaptans, sulfides and thiophenes. **ACG 275** is specifically designed for naphtha treatment units upstream of catalytic reformers or isomerization units.

Catalyst Management: Axens can assist with the disposal of spent **ACG 275.**

Typical Properties		
Trilobe extrudates		
Diameter	1.6	mm
Sock loading density	740	kg/m³
Dense loading density	850	kg/m³
Bulk Crushing Strength	0.7	MPa

Shipping Information	
Packaging	210 l. steel drums. Net 130 kg (287 lbs)
	208 l / 55 gallons. steel drums. Net 154 kg (340 lbs). Only for US market

Axens Reserves the right to change at its sole discretion, and without prior notice, all or part of the information contained in this document. Any technical or business related information described in this document is believed to be reliable. However, no representation or warrantly is made with respect thereto except as made by Axens in writing at the time of sale.

Version 17.2

Appendix F

Axens Group – Vendor Documentation

Axens SOLUTIONS

OIL REFINING | PETROCHEMICALS | GASES | RENEWABLES & ALTERNATIVES | WATER

Catalysts & Adsorbents

LOADING AND START-UP PROCEDURES

AxTrap 403

www.axens-solutions.net

89, Bd Franklin Roosevelt – 92500 Rueil-Malmaison – France

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This document contains confidential proprietary information belonging to Axens. It shall not be disclosed to any third parties without Axens' prior written consent.

1. PREPARATION OF THE UNIT

The following recommendations are of general type; hence do not apply to all circumstances which can appear in an industrial process unit. Suitable modifications may be necessary to accommodate each specific case.

Guard bed section is isolated by blinds from the rest of the unit and safety equipments are functioning properly (depressurization, pressure valves…).

The present document gives some general and simple rules to be followed before the start-up of a fresh guard bed material.

If a fresh guard bed material is to be loaded in a unit after water washing, cleaning or pressure tests under water, the unit must be swept with dry air or nitrogen for 6 hours minimum.

2. GUARD BED MATERIAL PACKAGING, HANDLING AND STORAGE

AxTrap™ 403 is delivered in steel drums. The guard bed material must be handled with care to avoid breakage of the guard bed material spheres. Guard bed material drums must not be rolled to minimized attrition of the product.

	Drum
Description	Steel drums (UN standard), Air tight cover. Thickness: 0.8 mm. Tare: 14.5 kg.
Dimension	Diameter: 0.6 m, height : 0.9 m
Net weight	120 kg

The guard bed material delivered in sealed steel drums should be stored in an enclosed and ventilated warehouse. The guard bed material must be stored in a cool, dry place out of direct sunlight and away from hot vessels, heaters, and other heat sources. It should not be stored in the vicinity of combustible materials. It should not come in contact with mineral acids, oxygen, or water. The storage time under such conditions can reach 2 years without any damage for the products and for the packaging.

Outdoor storage is possible, provided original packaging is stored under water-tight cover and raised above the naturally flood-free ground: Such storage is not recommended and should be minimized to reduce as much as possible the risk of water damage.

AxTrap™ 403 is a reduced and stabilized Ni based product, so AxTrap™ 403 is non-pyrophoric under ambient conditions. Nevertheless, reasonable precautions must always be observed.

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The AxTrap™ 403 drums are secured by spring-loaded sealing rings that may be sprung open by pulling on the handle of the catch mechanism. It is recommended that gloves be worn when releasing the sealing rings, as the edges of the drum may be sharp. Drums should remain closed until the last moment before loading. The drums must be re-closed during any breaks in the loading. Axens does not recommend storing opened drums. Instead of storing, Axens recommends loading the contents of the opened containers.

3. GUARD BED MATERIAL LOADING

3.1 Preliminary checking

- Check that process lines are properly isolated and blinded.
- Open the top manhole. Aerate and check that the atmosphere inside the reactor is suitable for entering.
- Check that the reactor is clean and dry.
- Make sure that the guard bed material and alumina or ceramics balls drums are gathered in a sheltered place, close to the reactor.
- Check the quality of the alumina or ceramic balls. If they are broken, they must be sorted and fines removed.
- Ensure that all the necessary safety and personnel protection equipment is available (gloves, dust masks, respirators, safety harness, etc...) as well as means of communication (walky-talkies).

3.2 Recommendations

- This step is the only one requiring vessel entry. Make sure that proper safety precautions are taken for the persons entering the vessel. Proper lighting, entry and access should be also provided.
- Under no circumstance should loading take place when it is raining. In case the guard bed loading is interrupted, it is mandatory to carefully close the reactor and maintain it under an inert gas blanket. Then, every hour the temperature inside the reactor must be checked. If there is a temperature increase, inert gas should be immediately re-admitted to the reactor to prevent further temperature increase.
- The drums containing guard bed material must be handled with care in order to minimize particle attrition. Covers must be installed at the top of each reactor on temporary structures to protect against rain.
- The loading is consequently done with a maximum of precautions to avoid dust formation by attrition.
- Guard bed material must be loaded carefully to minimize free fall. Maximum permissible free fall height is 1 meter.

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- Working in a dusty guard bed material atmosphere is not physically harmful, provided that dust masks are worn. Make sure that no foreign material is left in the reactor (pieces of sleeve, walking boards, tools, etc...).

3.3 Equipment and personnel

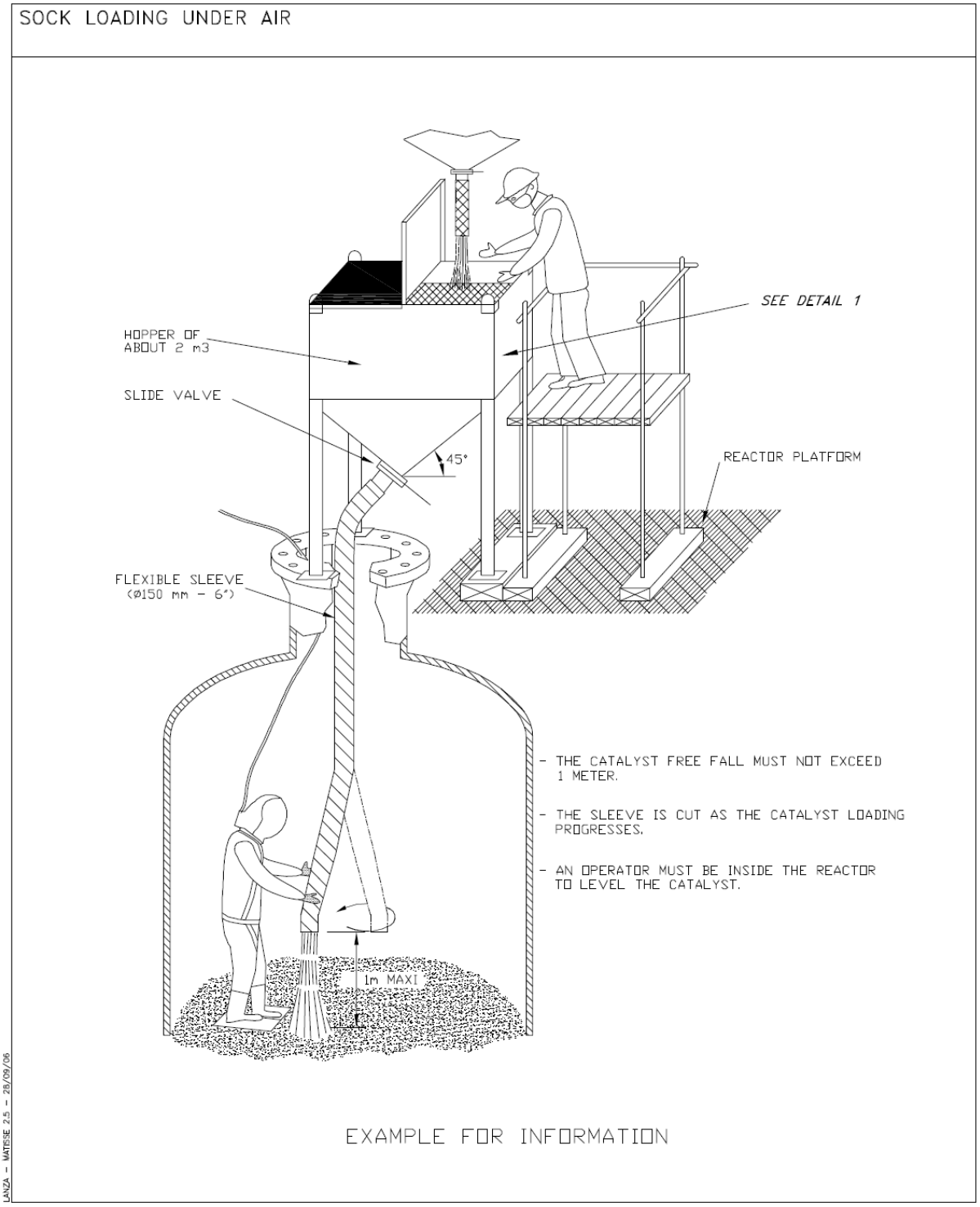
(Refer to the relevant drawing)

The list below is based on the following assumption: guard bed material loading will be carried out with a crane. The list may not be exhaustive of all the necessary equipment, but it can be used as a guideline.

- 1 telescopic crane capable of lifting about 3 tons, 5 meters above the guard bed reactor upper manhole (see drawing **"Catalyst handling – Loading with use of hopper**").
- 1 forklift to handle the guard bed material drum pallets (see drawing **"Filling-up of the hopper at ground level"**).
- Stationary hopper equipped with Ø 8 to 10" nozzles to be installed on the reactor upper manhole. The stationary hopper is fitted with a slide valve. The hopper legs should be long enough to allow access into the reactor (whenever possible) (see drawing **"Catalyst loading – Stationary hopper"**).
- To protect adsorbent from rain, temporary shelters are to be ready to use.
- Flexible sleeve of adequate length and 6" diameter.
- A vacuum cleaner should also be available to clean from dust and AxTrap™ 403 fines inside the reactor
- 2 mobile hoppers, each with a capacity of about 5 to 6 guard bed material drums (see drawings **"Catalyst loading – Shuttle hopper"** & **"Catalyst loading – Slide valve"**).
- 1 structure (scaffolding and timbers) to unload the drums into the mobile hoppers (see drawing **"Filling-up of the hopper at ground level"**).
- Inert gas source and related equipment for maintaining an inert atmosphere (nitrogen) in the reactor.
- Nitrogen flexible hoses with adapted fittings
- 1 safety harness, rope ladders, portable oxygen analyzer, thermal gun, low voltage lighting, dust masks, air masks, goggles, plastic sheets to protect drums and reactor in case of rain, sampling bottles for the guard bed material.

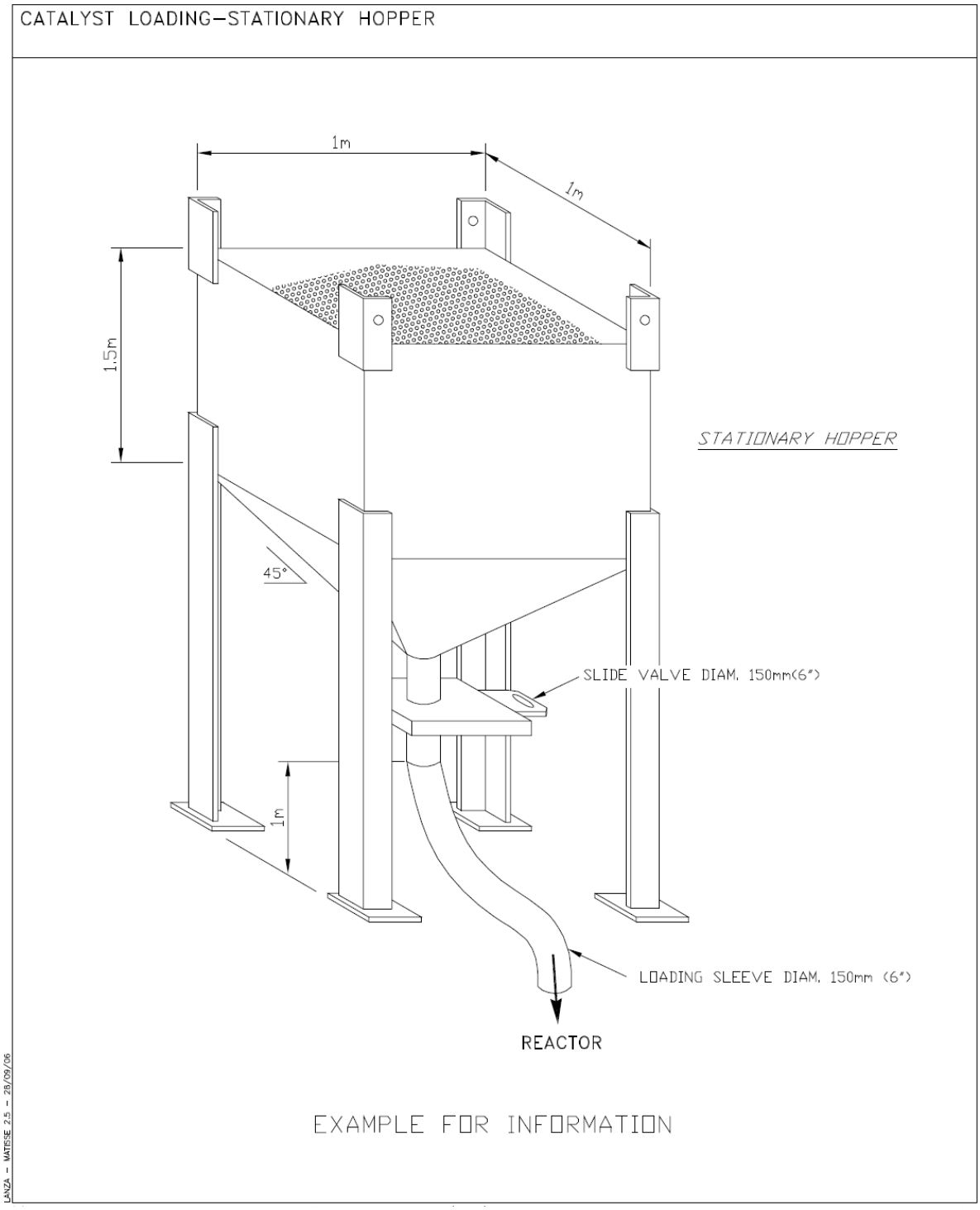
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Sock loading under air



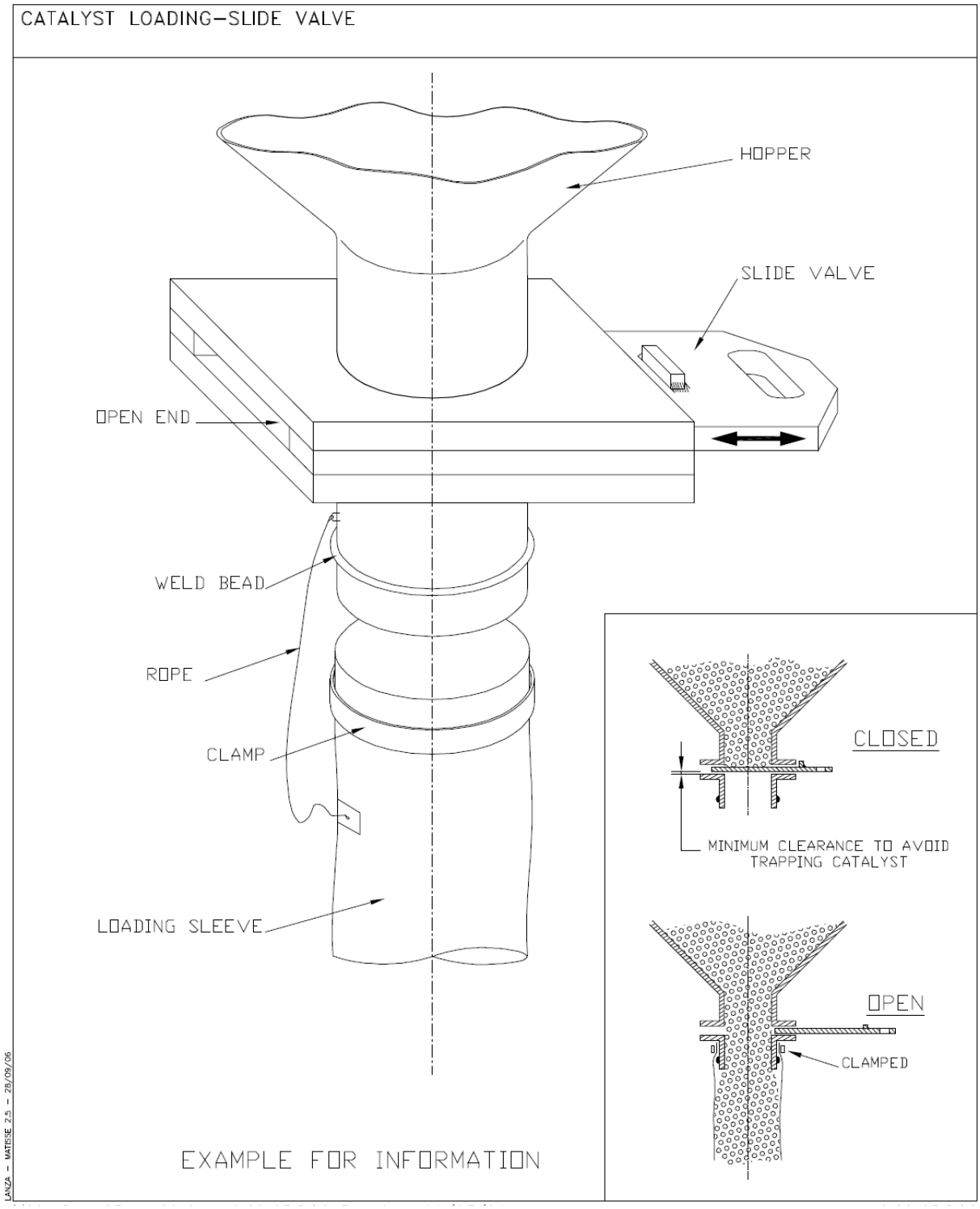
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Catalyst Loading – Stationary Hopper



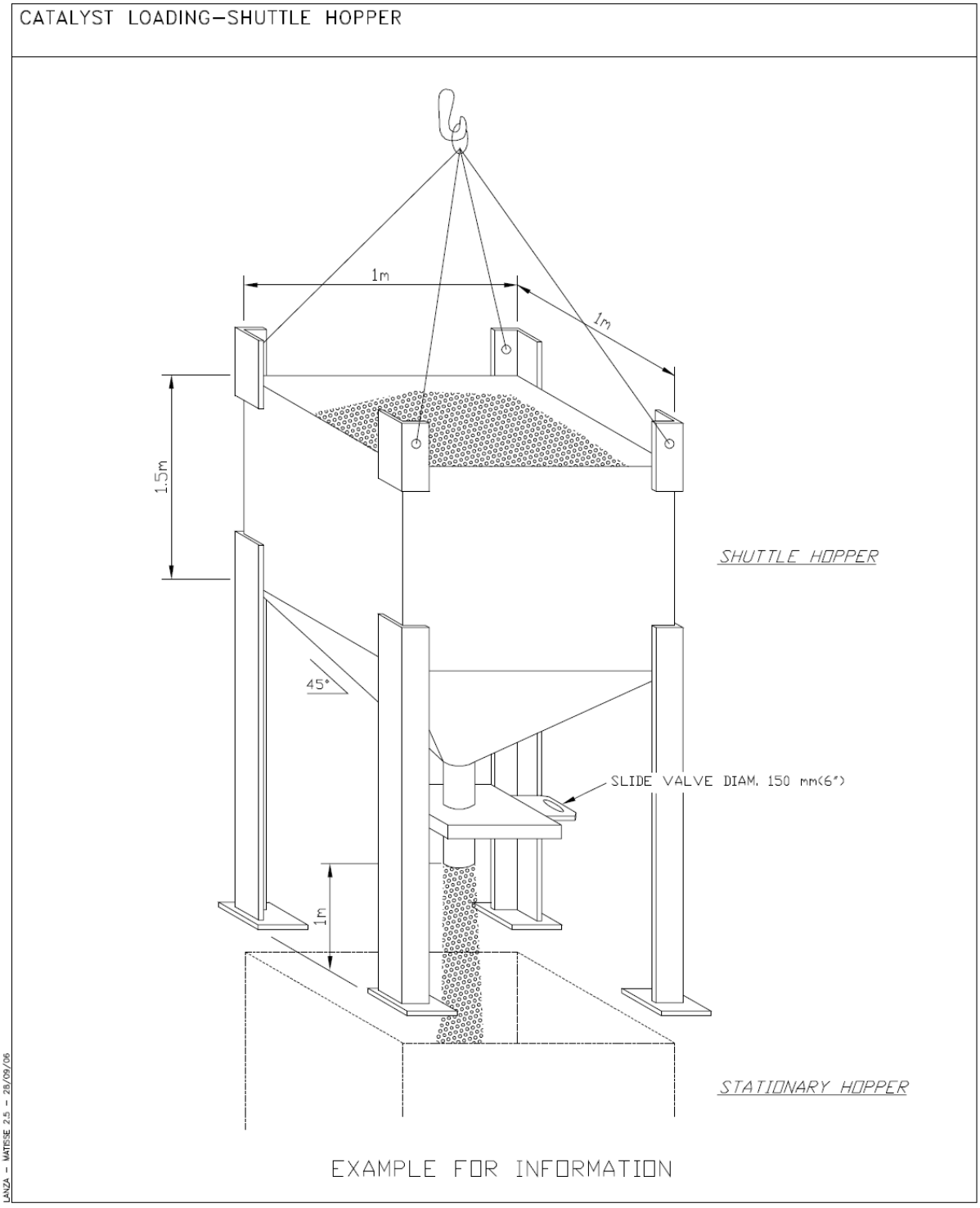
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Catalyst Loading – Slide valve



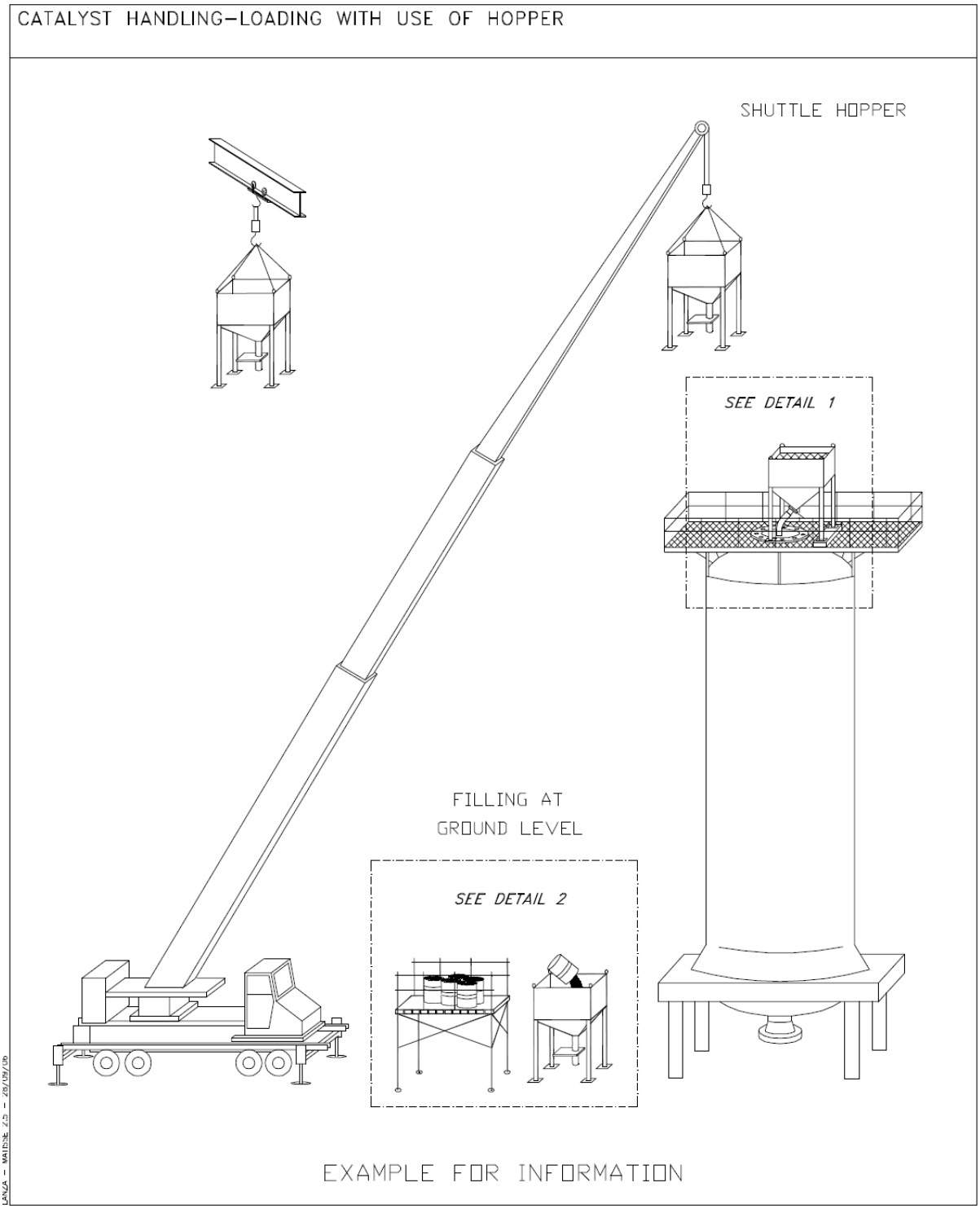
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Catalyst Loading – shuttle hopper



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Catalyst Handling – Loading with use of a Hopper

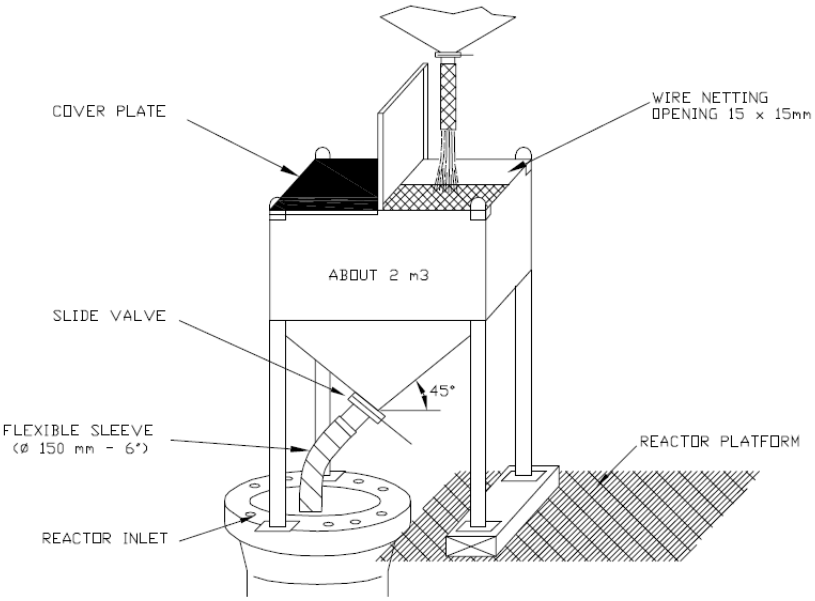


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Hopper Located On The Top Of Reactor - Under Air
Hopper Filling At Ground Level

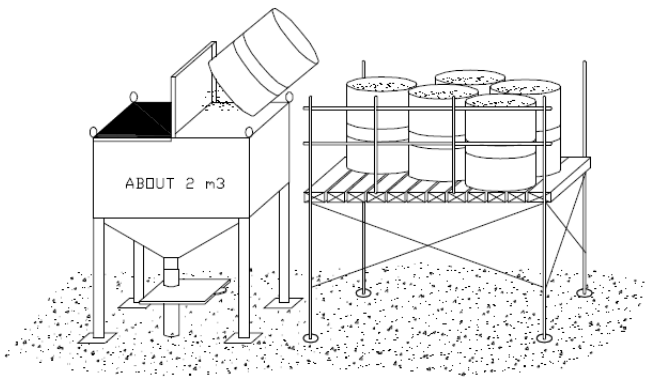
HOPPER LOCATED ON THE TOP OF REACTOR – UNDER AIR
HOPPER FILLING AT GROUND LEVEL

DETAIL 1



EXAMPLE FOR INFORMATION

DETAIL 2

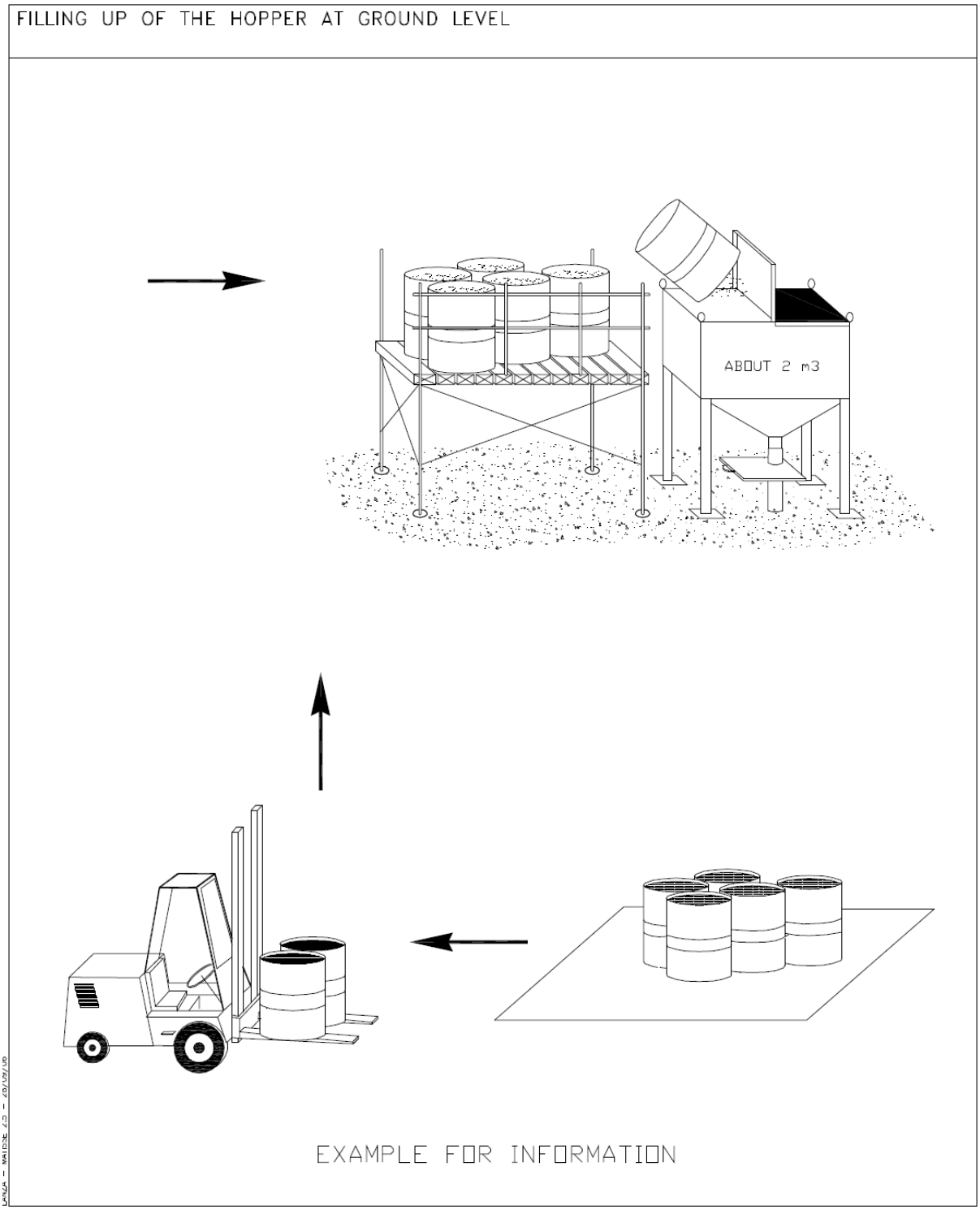


EXAMPLE FOR INFORMATION

LANZA – MATISSE 2.5 – 28/09/06

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Filling Up of the Hopper at Ground Level



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To serve the above mentioned equipment the following personnel is necessary:

- 1 foreman,
- 1 crane operator,
- 1 fork lift operator,
- 1 team of 4 riggers at ground level for guard bed material handling and loading into the mobile hoppers, 1 team of 6 fitters for vessels opening closing and for guard bed material loading,

Note: These personnel shall be permanently present during the loading operation. The total number of personnel will be obtained by multiplying by the number of shifts, if the loading takes place on a 24 hours basis. All personnel entering the vessel should be equipped with proper clothing to prevent contact between the skin and catalyst dust. Personnel entering the reactor must never walk directly on the catalyst being loaded. Plywood, plank supports, or snowshoes need to be used to distribute the weight over the catalyst surface to minimize catalyst breakage.

Important: The figures presented in this part are for technical purpose only. Refiner should adjust to local safety regulations to ensure enough personnel and equipments for safe guard bed material loading operation.

3.4 Guard bed material sock loading procedure

Important note: The procedure should be strictly followed to get expected AxTrap™ 403 performances.

The following guideline for the reactor loading assumes one guard bed material. It also assumes that the internals have been, first inspected in position, and then dismantled to speed up the loading process.

- Check that the quality of the guard bed material and the amount available are as specified. It is a good policy to write the guard bed material name and lot number of all loaded drums on a Guard bed material Loading Report (see below).
- Refer to the loading drawing (refer to process book relevant chapter) for the various heights of guard bed material and inert ball layers etc., and to the detail drawings for the installation of the internals. Inside the reactor measures will be taken from the welding line. Manufacturer's vessels measurements are generally shown from tangent lines. Make the necessary adjustment. Materialize the various levels with chalk or pencil marks on the reactor wall.
- Check that the outlet collector at the bottom of the reactor is properly mounted.
- Fit-in the close cover and the K-wool (fiber glass wool) plug in the guard bed material draw-off pipe.

  Important Note: Axens recommends performing the AxTrap™ 403 loading under inert atmosphere. The guard bed material is not pyrophoric, but rough handling during loading may cause exothermic reactions when in contact with air.
- Purge the reactor with inert gas such as nitrogen prior to the beginning of loading the guard bed material. The inert gas should be free of oxygen (<100 ppmv O_2) and moisture. During loading of the guard bed material, the vessel must be blanketed

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with inert gas and a small continuous purge must be kept in operation to prevent oxygen ingress into the vessel.

- Load the required volume of bottom inert balls as per the loading diagram and carefully level the surface. Then load the next layer of inert balls and carefully level the surface. Repeat this step for all the bottom inert ball layers. The inert balls need to be loaded using the flexible sleeve (free fall should not exceed 0.2 meter for the lower levels).
- Load the AxTrap™ 403 material with the sleeve. The person on the top of the vessel shall shorten the sleeve so that the free fall never exceeds one meter. Never dump the catalyst in one mound with the intent to level at the end, as this technique may result in a high concentration of fines in a section of the reactor directly under the loading sock. These fines could result in poor flow distribution of the reacting gas across the guard bed.
- When the upper level of the guard bed material is reached, stop loading the guard bed material and carefully level the surface.
- Install the top screen if required.
- Complete the top inert ball loading and carefully level the surface after each layer just likes for the bottom inert ball layers.
- Make sure that all debris and equipment used during the loading is removed from the reactor.
- Conduct any final inspections and reviews of the loading data that may be required.
- Reinstall the inlet distributor and loading manway cover.
- Keep the empty drums for unloading.

Note: During the guard bed loading, a sample could be taken in each drum to prepare a composite sample of the reactor load.

A loading report must be carefully filled with:

→ number of drums loaded in each bed,

→ guard bed material batch and drums reference numbers.

The loading density is checked at the end of the loading using the guard bed material loading report as described hereafter.

After closure vessel and prior to unit start-up, the vessel must be maintained under an inert atmosphere free of oxygen and moisture.

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Typical Guard bed material Loading Report

REACTOR LOADING REPORT UNIT NUMBER:								PLANT TYPE: LOCATION: COUNTRY :			
REACTOR: DATE: SHEET OF . GUARD BED MATERIAL TYPE:											
Drum	Lot No.	Drum No.	Net Wt	Drum	Lot No.	Drum No.	Net Wt	Drum	Lot No.	Drum No.	Net Wt
1				18				35			
2				19				36			
3				20				37			
4				21				38			
5				22				39			
6				23				40			
7				24				41			
8				25				42			
9				26				43			
10				27				44			
11				28				45			
12				29				46			
13				30				47			
14				31				48			
15				32				49			
16				33				50			
17				34				51			
TOTAL WEIGHT LOADED: NUMBER OF DRUMS: LOADING DENSITY:								LOADING SUPERVISOR NAME: SIGNATURE:			

As the adsorber is now under nitrogen atmosphere, any vessel entry requires adapted safety precautions and strict procedures. The presence of HSE coordinators and the use of adequate equipment such as self-contained breathing apparatus with air reserve, life line and harness are mandatory.

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4. START-UP PROCEDURE

4.1 General considerations

The following procedure uses hot desulfurized naphtha (HDN), in order to activate the AxTrap™ 403. The procedure starts during inert naphtha circulation, as soon as stripper operation is stable.

During activation, small quantities of adsorbed water will evolve.

4.2 Tightness Testing and Purging with nitrogen

Tightness test shall be performed using Nitrogen at the highest available pressure compatible with the adsorber and the nitrogen source. Use of Air is strictly prohibited. This would cause the adsorbent oxidation and an uncontrolled temperature increase of the adsorbent bed.

1. Pressure test sulfur guard vessel with nitrogen.
2. Check for gas leakage and tighten connections as necessary to minimize pressure loss.
3. Purge reactor vessel.

   Under no circumstances after this step should air or oxygen be allowed to re-enter the vessel.

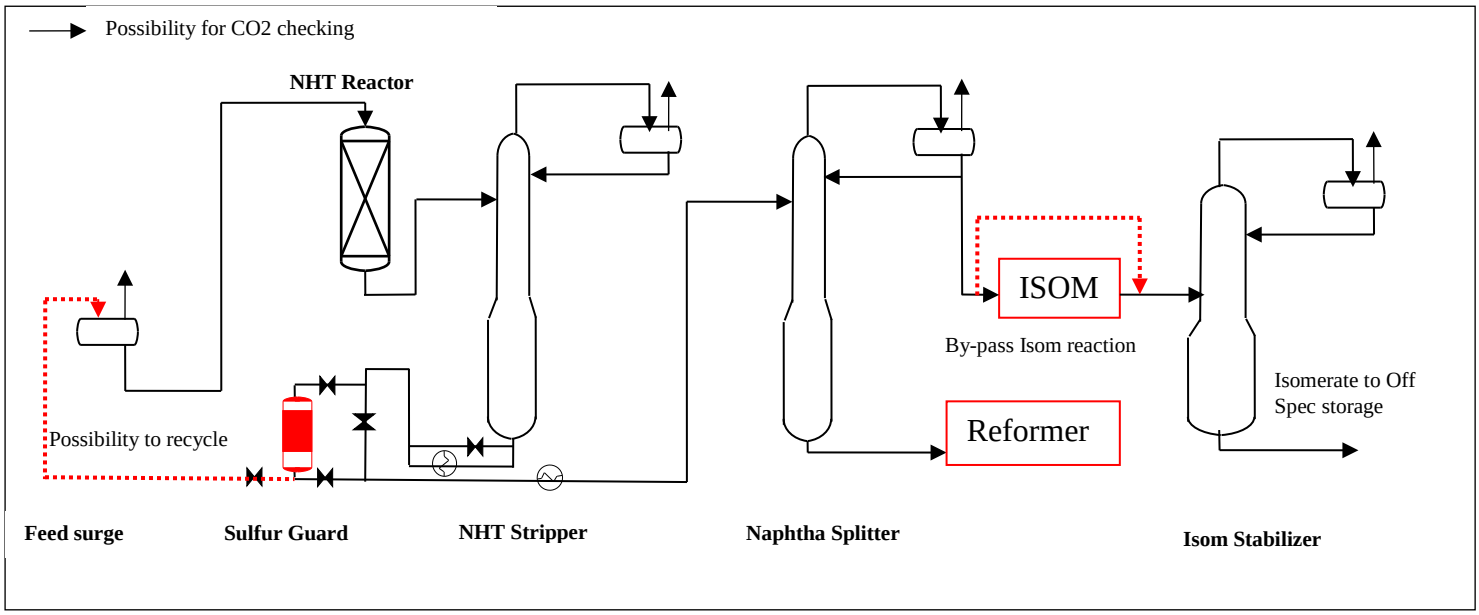
4. Pressure the reactor to 3.5 kg/cm^2 g and hold.
5. Check all attendant reactor piping for dead legs or low points which might contain oxygen. Vent the system as necessary to remove the oxygen in the piping.
6. Close blinds on nitrogen system.
7. Open blinds on Naphtha circuit.

4.3 Sulphur guard activation with hot feed and start-up procedure

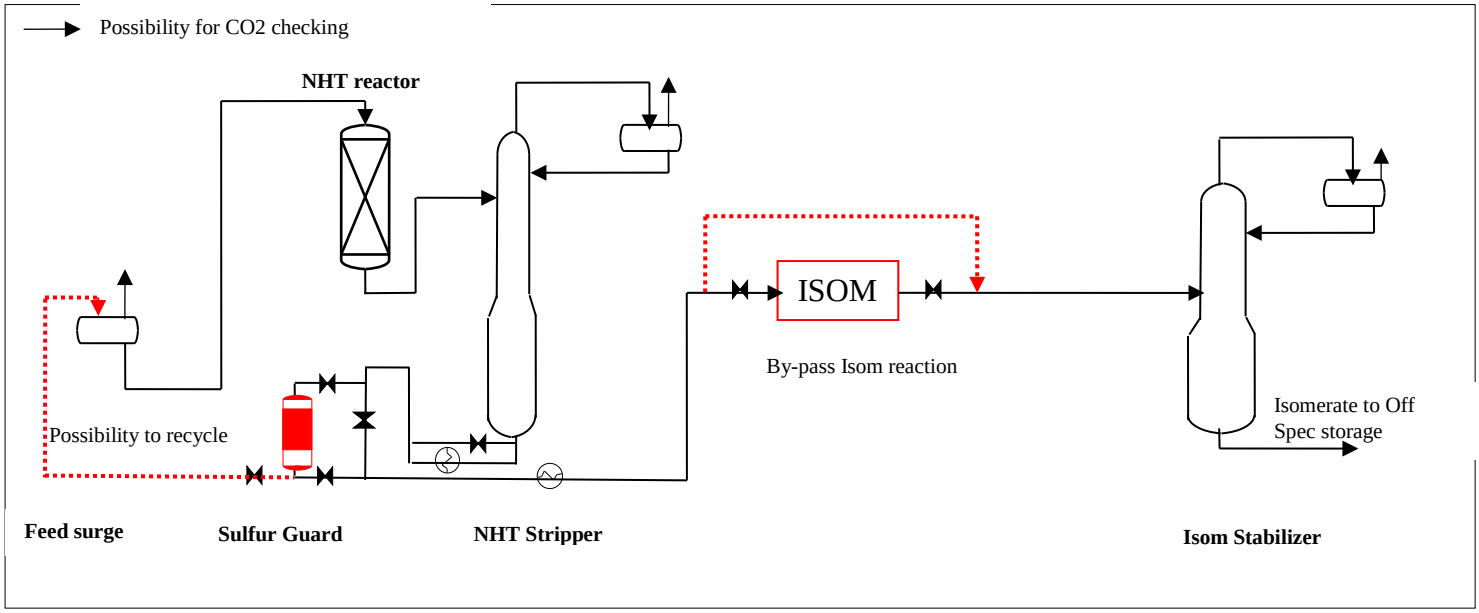
4.4

Case 1: Full range naphtha is treated in NHT and sulfur guard. In this case due to the presence of a naphtha splitter, it is possible to obtain a heavy naphtha cut free of H_2O, so the reformer unit can be in operation as long as the moisture in its recycle gas is monitored. Due to the very high sensitivity of Isomerization catalyst, Axens recommends bypassing the Isomerization unit.

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Case 2: Light Naphtha is treated in NHT and sulfur guard without naphtha splitter. In this case, due to the very high sensitivity of Isomerization catalyst, Axens recommends bypassing the Isomerization unit.



In both case, activation is performed by routing HDN with following specification through the AxTrap material:

- Sulphur content: 0.5 wt ppm maximum.
- O2/oxygenates content: 0.1 wt ppm maximum.
- 100% liquid, without H2.
- Operating temperature = normal operating temperature (minimum required temperature: 130°C).

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Status of the unit:

- The NHT reaction section and the stripper section have been started up successfully.
- The unit is running at minimum 60% of its design capacity.
- Sulphur is below 0.5 wtppm at stripper bottom.
- NHT stripper bottom is routed normally to downstream units (reaction section being by-passed or not),
- The sulfur guard bed is under nitrogen and by-passed.

Filling up and activation:

Introduce HDN with the following steps:

✓ Start to fill the vessel with a slipstream from NHT stripper bottom. Filling is slightly exothermal process due to heat of adsorption (an increase of 30°C is expected). Filling up flow-rate is manually adjusted by globe valve on filling up lines and local flow-meter.

NB: Liquid filling up is up flow, flow rate should be limited to avoid any fluidization of guard bed. Maximum velocity through the guard bed is 10 cm/min.

✓ During filling up, nitrogen is evacuated through PSV bypasses. Filling is completed when liquid is flowing through sight glass without bubbles.

✓ When the guard bed is successfully filled, close the valves on the filling lines which are located at the guard bed bottom, then line up for guard bed activation.

- Open sulphur guard inlet valve.
- Gradually close the guard by-pass valve.
- Circulation of naphtha starts (partially in closed loop, naphtha is recirculated back to unit feed drum).
- Maintain hot circulation.

Estimated duration of activation: between 3-5 hours (based on 60% of unit capacity). Duration will depend on amount of feed bypassing the guard bed.

Remarks:

- In the unlikely case that an extraordinary exotherm occurs, it will probably be due to the presence of hydrogen, either as such or in combination with, carbon monoxide or oxygen (see appendix).
- As potential desorption begins, route naphtha to off-spec storage.
- As off-spec naphtha is sent to storage, feed the unit with naphtha from outside battery limit.
- Any feed driers (if applicable) downstream of the sulphur guard bed should be regenerated as soon as the guard bed unit has been on-line for 24 hours.

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4.4 Alternate case: Guard activation with hot nitrogen or hot natural gas sweeping and start-up procedure

Remark: this procedure leads to a large nitrogen consumption and is essentially applicable when hot desulfurized feed is not available.

Most of the H_2O can be removed by heating the guard with a dry nitrogen gas at ambient pressure. A bed activation temperature of 170°C is recommended.

The activation procedure does not make the guard completely immune to exotherm when contacting it with process fluid. The adsorption of liquid (and H_2O, if present) on a freshly activated surface may also be exothermic.

Following hot nitrogen activation, the catalyst should be cooled under N_2 to 100°C or less to allow for possible exotherms when the liquid feed is introduced.
The following general destabilization (activation) guidelines are suggested. Each specific guard bed configuration may require modifications to these guidelines.

- Reaction section is leak tested with N_2. It is important that the N_2 contain less than 10 ppm O_2 to avoid oxidation of the nickel during the heat-up stage of the operation. Purge the catalyst free of oxygen with N_2.
- At ambient pressure, begin flow of dry N_2, venting **to atmosphere** or flare. Flow rates are dependent on the user's facilities. Flow rate is not critical, but should be based upon the desired heat-up rate. Flow rates of 200 Nm3 minimum per hour per m3 of catalyst would be preferred.
- Establish N_2 flow-rates and begin heating the nitrogen at a rate of 15 - 30°C/hour to the activation temperature 170°C. Once the catalyst bed has obtained a uniform temperature of 170°C, hold at this activation temperature for at least 4 hours.
- With the N_2 still flowing, lower the bed temperature to below 100°C and then slowly pressurize the unit to operating pressure.
- With the system at operating pressure and the guard bed temperatures lined out at below normal start-up, fill up the vessel in up flow (maximum velocity through the guard bed is 10 cm/min). Nitrogen is evacuated through PSVs by-pass. When sulphur guard bed filling phase is achieved, close valves on filling lines which are located at the guard bed bottom, then line up guard bed in normal operation.
- The hot feed is required to fully complete the activation phase. Any feed driers downstream of the sulphur guard bed should be regenerated as soon as the guard bed unit has been on-line for 24 hours.

4.5 Operating variables

The sulfur guard unit operates with minimal attention during its normal cycle life. The most important operational data to watch is guard bed temperatures. During normal processing, there should be no exotherm for design levels of sulfur. Any noticeable exotherm should be treated with caution.

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Upstream feed preparation must at all times provide:

- Hydrogen removal
- Carbon Oxides removal (CO, CO_2)
- Oxygen removal
- Moisture removal

If an exotherm occurs precautions should be taken to:

- Remove and eliminate naphtha feed and inert blanket the catalyst.
- Find the source of the exotherm.

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5. AxTrap™ 403 SHUTDOWN / UNLOADING PROCEDURES

5.1 Shutdown

5.1.1 No Change out of adsorbent planned

1. Open reactor by-pass.
2. Close inlet and outlet valves.
3. Leave reactor liquid filled.

5.1.2 Change out of adsorbent is planned

1. Open reactor bypass.
2. Close inlet valves.
3. Depressurize liquid to downstream vessels or flare.
4. Pressurize the reactor again with nitrogen and depressurize to fully rid the reactor system of liquid.

5.2 Adsorbent Dumping

Note: The spent AxTrap™ 403 when dry is pyrophoric on contact with air. Every precaution should be taken to assure that the used AxTrap™ 403 does not contact air.

1. Cool the reactor with nitrogen purge.
2. Pressurize the reactor with nitrogen to 0.7 barg at all times to assure that air is excluded.
3. After the reactor bed has cooled to 50°C place a drum partially filled with water under the dump nozzle. Have a water hose readily accessible to wet the catalyst as it falls from the dump nozzle. When catalyst dumping is complete, each drum should be filled with water and sealed. Alternatively, if vessel and foundation design allows, the drum may be flooded with appropriately clean water and unloaded with the catalyst saturated with water.
4. Using the blind flange covering the dump nozzle as a gate valve, swing the flange upward pivoting on a top bolt. Inert balls should fall out first. If the inert balls or catalyst bridge at the exit, use a rod to break up the bridging to facilitate the flow. If the reactor vessel is equipped with more than one dump nozzle, discharge catalyst from each location until no more catalyst can be obtained.
5. A heel of catalyst/inert balls (less that 10% of catalyst) will remain after all that is possible is removed using the dump nozzle(s). To remove the remaining heel the bottom exit elbow and outlet collector will have to be removed or swing away from the outlet.
6. Remove bottom exit piping and outlet collector. Dump remaining inert balls and catalyst in the vessel skirt. Spray water on the catalyst as it collects in the skirt.
7. Shovel the wetted catalyst/inert balls into drums.

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Note:

- The inert balls can be reused if a wet screening is done to assure that air is prevented from reaching the used AxTrap™ 403.
- The spent AxTrap™ 403 is a valuable source of nickel metal to steel manufacturers. There are various brokers worldwide who can handle the spent material for at least transportation cost to the steel mill site. Please contact your local Axens representative if more information is needed on this disposal option.
- Some nickel sulphide may be present in spent AxTrap™ 403. This hazardous material would require special handling procedures. A spent catalyst analysis and spent catalyst Material Safety Data Sheet, at a minimum, will need to be provided to the recycler.

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Appendix:

AxTrap™ 403 Material Safety Data Sheet.

Concerning catalysts/adsorbents supplied under a trade mark, the relevant updated Material Safety Data Sheets must be required from the manufacturer.
The European Directive instructs all companies supplying products, to provide product **Safety Data Sheets** in a controlled manner. Please contact your Axens representative for this material.

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