RNG WORKS

THE COALITION FOR RENEWABLE NATURAL GAS

Planning-Stage Knowledge & Tools to Inform H_2S Removal Media Selection & Process Design Considerations

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Why Treat H_2S?

Typical Decision-Drivers

- Maintenance Cost Reduction
- Warranty/Performance Limitations
- Emissions Requirements
- Pipeline/CNG Specifications

*For downstream equipment

These clearly are not mutually exclusive goals, but the range of available technologies for H_2S removal includes options that meet some of these objectives "better" than others, or in some cases, not at all.

Why Treat H_2S?

SO_2 Emissions

- National and State Regulations
- Site-dependent Permits
- State Implementation Plans (SIPS)
- Attainment vs. Non-Attainment Areas

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

H_2S will combust to form sulfur oxides (SOx) impacting emission quality and potentially increasing costs due to required auxiliary equipment, permitting and obligatory monitoring.

Pipeline CNG/RNG Specifications

H_2S and Sulfur Pipeline Limits

- Pipeline limits for H_2S are measured in grains/100 ft^3

  Typically < 0.25 grains/100 ft^3 of H_2S

  OR

  4 ppm of H_2S (1 grain/100 ft^3 of H_2S = ~ 16 ppm of H_2S)

- Pipeline limits for total sulfur are typically < 1 grain/100 ft^3 of sulfur

  OR

  16 ppm of total sulfur

Design Considerations: Gas Constituents

Be aware of other sulfurs & mercaptans present in gas composition.

Common Sulfides

- Carbonyl Sulfide – COS
- Dimethyl Sulfide – DMS

Common Mercaptans

- Methyl Mercaptan – MeSH
- Ethyl Mercaptan - EtSH

Common Disulfides

- Carbon Disulfide – CS2
- Dimethyl Disulfides – DMDS

Typically not in biogas, but may show up in LFG or dry fermentation digesters

H_2S Scrubber Design Considerations

How to design an H2S scrubber to meet pipeline specifications

- The outlet sulfur concentration does not need to meet the pipeline specification.
- A reasonable H_2S outlet concentration should be in the 20-25 ppm range.
- After the biogas exits the H_2S scrubber, low levels of H_2S will be removed by downstream processes.

Design Considerations: Cost

The higher the H2S outlet concentration the lower the capital and operating cost.

- Smaller system
- Longer bed life

Effects of Design Outlet H_2S on Operating Cost

Flow Rate	1000	scfm
H_2S Concentration	1000	ppm
	Scenario	
	2 ppm	25 ppm
Bed Life (days)	121	136
Media Cost	$189,136	$168,276
Changeout Cost	$30,165	$26,838
Total Cost	$219,302	$195,114
Cost / lb. of H2S Removed	$4.90	$3.87
Changeout Frequency (months)	4.0	4.5

Design Considerations

Operating requirements can dictate media selection.

- **How much H_2S produced per year?** Flow (scfm) and H_2S concentration (ppm).
- **Gas Constituents:** How much O_2 is present in the biogas? Other constituents.
- **Temperature:** What is the Temperature of the biogas at point of treatment?
- **Saturation:** What is the Saturation level of the biogas?
- **Operation Pressure:** What is the Operating pressure at the point of H_2S treatment?
  - For RNG should be under pressure
- **What Methane upgrading equipment will be utilized?**
  - PSA
  - Membranes
  - Water wash

Design Input: Media Cost-efficiency

A general rule of thumb for H_2S removal media selection: type chosen is based on annual H_2S removal requirement.

- **Flow Rate x H_2S Concentration x Time (year) x 0.096 X 10^{-6} = Pounds/Year**
  - Below 30,000 pounds H_2S /year, we recommend AxTrap.
  - Above 30,000 pounds H_2S/year but below 300,000, we recommend iron sponge.

Baseline for System Comparison

Pounds of H_2S Generated on an Annual Basis

Flow Rate (scfm)	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500
2500	63,072	94,608	126,144	157,680	189,216	220,752	252,288	283,824	315,360	346,896	378,432	409,968	441,504
2400	60,549	90,824	121,098	151,373	181,647	211,922	242,196	272,471	302,746	333,020	363,295	393,569	423,844
2300	58,026	87,039	116,052	145,066	174,079	203,092	232,105	261,118	290,131	319,144	348,157	377,171	406,184
2200	55,503	83,255	111,007	138,758	166,510	194,262	222,013	249,765	277,517	305,268	333,020	360,772	388,524
2100	52,980	79,471	105,961	132,451	158,941	185,432	211,922	238,412	264,902	291,393	317,883	344,373	370,863
2000	50,458	75,686	100,915	126,144	151,373	176,602	201,830	227,059	252,288	277,517	302,746	327,974	353,203
1900	47,935	71,902	95,869	119,837	143,804	167,772	191,739	215,706	239,674	263,641	287,608	311,576	335,543
1800	45,412	68,118	90,824	113,530	136,236	158,941	181,647	204,353	227,059	249,765	272,471	295,177	317,883
1700	42,889	64,333	85,778	107,222	128,667	150,111	171,556	193,000	214,445	235,889	257,334	278,778	300,223
1600	40,366	60,549	80,732	100,915	121,098	141,281	161,464	181,647	201,830	222,013	242,196	262,380	282,563
1500	37,843	56,765	75,686	94,608	113,530	132,451	151,373	170,294	189,216	208,138	227,059	245,981	264,902
1400	35,320	52,980	70,641	88,301	105,961	123,621	141,281	158,941	176,602	194,262	211,922	229,582	247,242
1300	32,797	49,196	65,595	81,994	98,392	114,791	131,190	147,588	163,987	180,386	196,785	213,183	229,582
1200	30,275	45,412	60,549	75,686	90,824	105,961	121,098	136,236	151,373	166,510	181,647	196,785	211,922
1100	27,752	41,628	55,503	69,379	83,255	97,131	111,007	124,883	138,758	152,634	166,510	180,386	194,262
1000	25,229	37,843	50,458	63,072	75,686	88,301	100,915	113,530	126,144	138,758	151,373	163,987	176,602
900	22,706	34,059	45,412	56,765	68,118	79,471	90,824	102,177	113,530	124,883	136,236	147,588	158,941
800	20,183	30,275	40,366	50,458	60,549	70,641	80,732	90,824	100,915	111,007	121,098	131,190	141,281
700	17,660	26,490	35,320	44,150	52,980	61,811	70,641	79,471	88,301	97,131	105,961	114,791	123,621
600	15,137	22,706	30,275	37,843	45,412	52,980	60,549	68,118	75,686	83,255	90,824	98,392	105,961
500	12,614	18,922	25,229	31,536	37,843	44,150	50,458	56,765	63,072	69,379	75,686	81,994	88,301
400	10,092	15,137	20,183	25,229	30,275	35,320	40,366	45,412	50,458	55,503	60,549	65,595	70,641
300	7,569	11,353	15,137	18,922	22,706	26,490	30,275	34,059	37,843	41,628	45,412	49,196	52,980
200	5,046	7,569	10,092	12,614	15,137	17,660	20,183	22,706	25,229	27,752	30,275	32,797	35,320
100	2,523	3,784	5,046	6,307	7,569	8,830	10,092	11,353	12,614	13,876	15,137	16,399	17,660

H_2S Concentration (ppm)

Red = Granular
Blue = Iron Sponge
Black = Other

Design Parameter Considerations

CapEx

- Vessel Material (Steel, FRP, Carbon)
- Avail. Footprint
- System size
  - # of Vessels
  - Horsepower (blower size/cost)
- Downtime

OpEx

- Bed life / Changeout frequency
  - Labor
  - Media Cost & Freight
- Utilities/Power
- Operator Attention

Design Parameter Considerations: Gas Constituents

Understand gas composition to evaluate performance expectations for removal efficiency of various technologies and media types.

- Siloxanes
- O_2
- H_2S
- R.H.
- VOCs

For example, if siloxane removal is required, the hydrogen sulfide concentration in the gas stream must be less than 20ppm to ensure optimum siloxane media life.

Design Considerations: Temperature

Maximum temperature may dictate H_2S removal media selection

- The biogas temperature for iron sponge should be between 32°F - 110°F.
- The biogas temperature for AxTrap should be between 32°F-190°F.
- The biogas temperature for Darco should be < 160°F.

Design Considerations: RH Saturation

Saturation level of the biogas

- Both iron sponge and AxTrap granular media work best if the biogas is saturated.
- Darco must be greater than 60% RH.
- If the iron oxide dries out it loses its ability to react with the H_2S.
  - Iron sponge cannot be re-hydrated.
  - AxTrap can be re-hydrated.
- MV adds small amounts of water to the iron sponge on a daily basis to maintain the moisture content.

Design Considerations: O_2

O_2 requirement for media removal efficiency

- When O_2 is present in the biogas in a ratio of 5:1 (O_2:H_2S) it doubles the bed life of both iron sponge and AxTrap.
  - O_2 is consumed at a 1:1 ratio in the process.
  - Typically there is enough O_2 present in LFG

- No O_2 in the biogas or cannot be added MV would recommend AxTrap

- Darco the ratio must be 4:1 (O_2:H_2S)

Design Considerations: Operating Pressure

Operating Pressure related to Process Design

- MV does not recommend installing the H_2S removal system under vacuum for RNG projects.
  - Point of air intrusion

- MV does not recommend the use of Iron Sponge above 5 PSI
  - MV uses a fully removable lid with Iron Sponge
  - The fully removable lid works in conjunction with MVNets
  - Above 5 PSI it is difficult to get the lid to seal

- Both AxTrap and Darco are easily loaded and removed through manways and a vacuum truck

Design Considerations: PSA

Typically MV has been asked to treat the off gas of a PSA system.

In relation to PSA:

- Plenty of O_2
- Less capital because you are treating about half the flow rate

MV typically recommends iron sponge for this application.
We have had requests where the H_2S levels were relatively high, and the client wanted to remove the H_2S before separation.

Design Considerations: Water Wash

MV does not typically quote systems utilizing water wash, as H_2S is highly soluble in water and is removed efficiently in the process.

Emission limits may require it to be treated in the off gas though. This would be similar to treating the off gas in a PSA.

Design Considerations: Membranes

Membranes are sensitive to H_2S

- Membranes utilize activated carbon as a guard bed to protect the membranes from H_2S, VOCs, siloxanes.
- The AC guard bed enables us to increase the H_2S outlet concentration to 50 ppm.

Design Considerations: Ideal Design Recap

Placement of H_2S scrubber in the process is critical

- Before Dehydration
- Before Siloxane Removal
- Before Compression

Dry Scrubbers: Why are dry scrubbers often selected?

Often Most Cost-Effective for Typical Digester Biogas and LFG Projects

- Lower utility requirements
- Minimal operator attention
- Forgiving of fluctuating inlet conditions to deliver constant outlet conditions
- Lower capital investment for applications generating < 300,000 lbs. H_2S/Year

Cost-Effective Dry Scrubber Technologies

Enhanced Iron Sponge-based Systems

B.A.M.™

- Wood chip substrate
- Lower operating cost
- Lowest cost per pound of H_2S removed.
- Removes min. of 6 lbs. and systems can be optimized (w/ O_2) to remove up to 13 lbs. per ft^3
- Requires crane or excavator to remove media
- Typically a larger footprint than granular system
- Spent media is non-hazardous and can be disposed of in a landfill

Cost-Effective Dry Scrubber Technologies

Most Common Granular Iron Oxide Media

AxTrap™

- Zeolite base
- Lower pressure drop
- Unique iron-oxide matrix of the AxTrap media avoids the excessive heating and combustion
- Non-binding reaction
- Generally removes up to 14 lbs. and systems optimizes may remove up to 20 lbs. per ft^3
- Requires fully saturated LFG but not affected by free liquids
- Even greater ease of media removal than other systems

Cost-Effective Dry Scrubber Technologies

Activated Carbon

DARCO® BG1 Activated Carbon

- 40% sulfur loading by weight
- Easy to remove
- Natural product w/out chemical impregnates
- **Operating** condition requirements for DARCO products are
  - H_2S: 1 – 3,000 PPM
  - RH: +60%
  - O2: 4:1 vs. H2S
  - H_2S removal uses catalytic reaction: BG1 needs 5-7 sec. contact time
  - Temp < 160 degrees F

Removal of Dry Scrubber Media: Videos

Scan here to see iron sponge media removal

PRIVACY.FLOWCODE.COM

Scan here to see granular media removal

PRIVACY.FLOWCODE.COM

The Case for Adding O_2

You Can Add O_2 and Still Meet Pipeline Specs

- Pipeline limits for O_2 typically range from 0.2% (2000 ppm) to 1% (10,000 ppm)
- Adding O_2 (5:1 ratio) doubles the bed life of the media cutting operating cost in half
    - For Darco the ratio is 4:1, which Darco needs to be utilized
- Small amounts of O_2 will be removed by downstream processes

Iron Sponge OpEx Cost Comparison – O_2 v. w/o O_2

	Scenario	
	Oxygen	No Oxygen
Bed Life (days)	276	128
Media Cost	$69,864	$151,373
Changeout Cost	$39,606	$85,812
Oxygen Cost	$30,000	N/A
Total Cost	$139,470	$237,185
Cost / lb. of H2S Removed	$2.72	$4.70
Changeout Frequency (months)	9.2	4.3

AxTrap 4142 OpEx Cost Comparison – O_2 v. w/o O_2

Flow Rate	1000	scfm
H_2S Concentration	1000	ppm
	Scenario	
	Oxygen	No Oxygen
Bed Life (days)	340	170
Media Cost	$95,400	$190,800
Changeout Cost	$21,470	$42,940
Oxygen	$30,000	N/A
Total Cost	$146,870	$233,740
Cost / lb. of H2S Removed	$3.12	$4.96
Changeout Frequency (months)	11.2	5.6

Got Questions?

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