



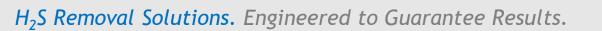
### Planning-Stage Knowledge & Tools to Inform H<sub>2</sub>S Removal Media Selection & Process Design Considerations

MV Technologies mvseer.com

# **MV TECHNOLOGIES**



## Planning-Stage Knowledge & Tools to Inform H<sub>2</sub>S Removal Media Selection & Process Design Considerations





## Discussion

- I. Why Treat  $H_2S$ ?
- II. Pipeline CNG/RNG Specification Considerations
- III. H<sub>2</sub>S Scrubber Design Input
- IV. Why Dry Scrubbers are Often Selected
- V. Dry Scrubber Media Technologies
- VI. The Case For Adding  $O_2$

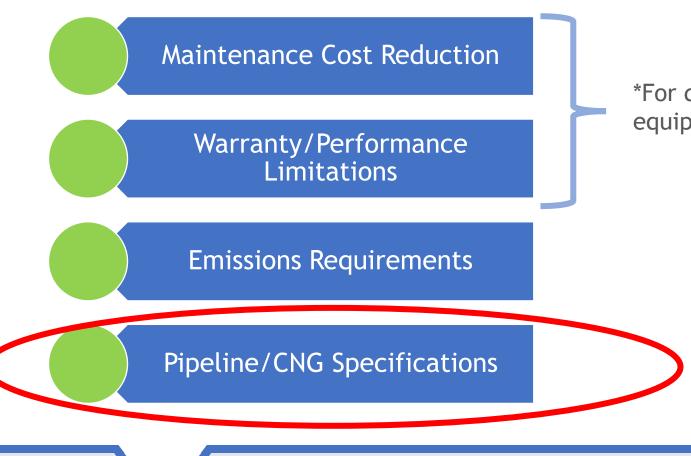






## Why Treat H<sub>2</sub>S?

#### **Typical Decision-Drivers**



\*For downstream equipment

These clearly are not mutually exclusive goals, but the range of available technologies for H<sub>2</sub>S removal includes options that meet some of these objectives "better" than others, or in some cases, not at all.



## SO<sub>2</sub> Emissions

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



 $H_2S$  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

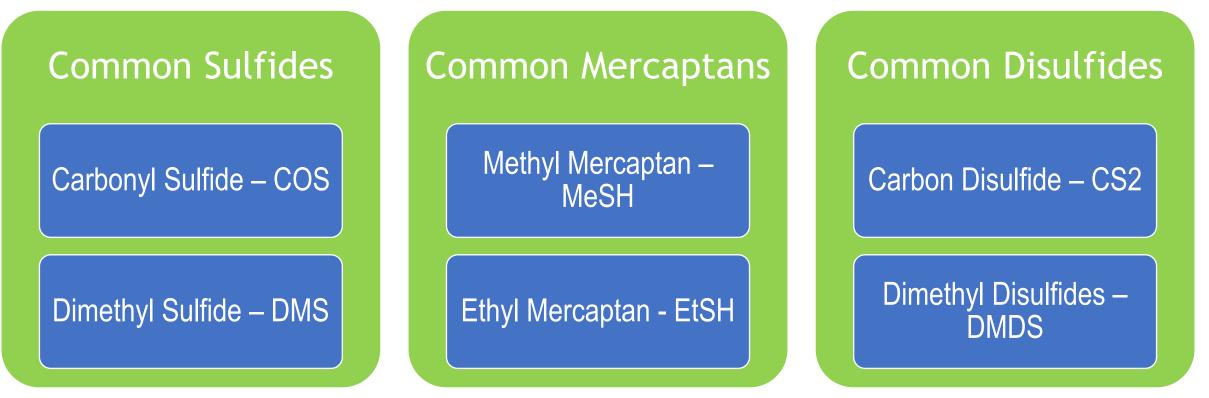
## H<sub>2</sub>S and Sulfur Pipeline Limits

- Pipeline limits for H<sub>2</sub>S are measured in grains/100 ft<sup>3</sup> Typically < 0.25 grains/100 ft<sup>3</sup> of H<sub>2</sub>S OR 4 ppm of H<sub>2</sub>S (1 grain/100 ft<sup>3</sup> of H<sub>2</sub>S = ~ 16 ppm of H<sub>2</sub>S)
- Pipeline limits for total sulfur are typically < 1 grain/100 ft<sup>3</sup> of sulfur OR 16 ppm of total sulfur



## Design Considerations: Gas Constituents

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



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



## H<sub>2</sub>S 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<sub>2</sub>S scrubber, low levels of H<sub>2</sub>S 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<sub>2</sub>S on Operating Cost

Flow Rate	1000	scfm			
H <sub>2</sub> S 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<sub>2</sub>S produced per year? Flow (scfm) and H<sub>2</sub>S concentration (ppm).
- **Gas Constituents:** How much O<sub>2</sub> 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<sub>2</sub>S 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<sub>2</sub>S removal media selection: type chosen is based on annual H<sub>2</sub>S removal requirement.

- Flow Rate x  $H_2$ S Concentration x Time (year) x 0.096 X 10<sup>-6</sup> = Pounds/Year
  - Below 30,000 pounds  $H_2S$  /year, we recommend AxTrap.
  - Above 30,000 pounds H<sub>2</sub>S/year but below 300,000, we recommend iron sponge.





## Baseline for System Comparison

Pounds of H <sub>2</sub> S Generated on	an Annual Basis
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Founds of Ti <sub>2</sub> 5 Generated off an Annual Dasis														
	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
		500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500
		-				H <sub>2</sub> S (	Concent	tration	(ppm)					
						<b>L</b> -			<b>NI /</b>					

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



- 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<sub>2</sub>
- H<sub>2</sub>S
- 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<sub>2</sub>S 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  $< 160^{\circ}$ 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<sub>2</sub>

#### O<sub>2</sub> requirement for media removal efficiency

- When O<sub>2</sub> is present in the biogas in a ratio of 5:1 (O<sub>2</sub>:H<sub>2</sub>S) 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<sub>2</sub> present in LFG
- No O<sub>2</sub> in the biogas or cannot be added MV would recommend AxTrap
- Darco the ratio must be 4:1 (O<sub>2</sub>:H<sub>2</sub>S)





## **Design Considerations: Operating Pressure**

#### **Operating Pressure related to Process Design**

- $\circ$  MV does not recommend installing the H<sub>2</sub>S removal system under vacuum for RNG projects.
  - Point of air intrusion
- $\,\circ\,$  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<sub>2</sub>
- 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<sub>2</sub>S

- Membranes utilize activated carbon as a guard bed to protect the membranes from H<sub>2</sub>S, 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<sub>2</sub>S 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<sub>2</sub>S/Year



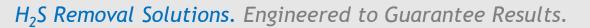


## **Cost-Effective Dry Scrubber Technologies**

#### Enhanced Iron Sponge-based Systems

#### **B.A.M.**<sup>TM</sup>

- Wood chip substrate
- Lower operating cost
- Lowest cost per pound of H<sub>2</sub>S removed.
- Removes min. of 6 lbs. and systems can be optimized (w/ O<sub>2</sub>) to remove up to 13 lbs. per ft<sup>3</sup>
- 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





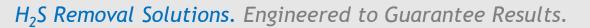


## Cost-Effective Dry Scrubber Technologies

#### Most Common Granular Iron Oxide Media

#### **AxTrap**<sup>™</sup>

- 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<sup>3</sup>
- 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** 

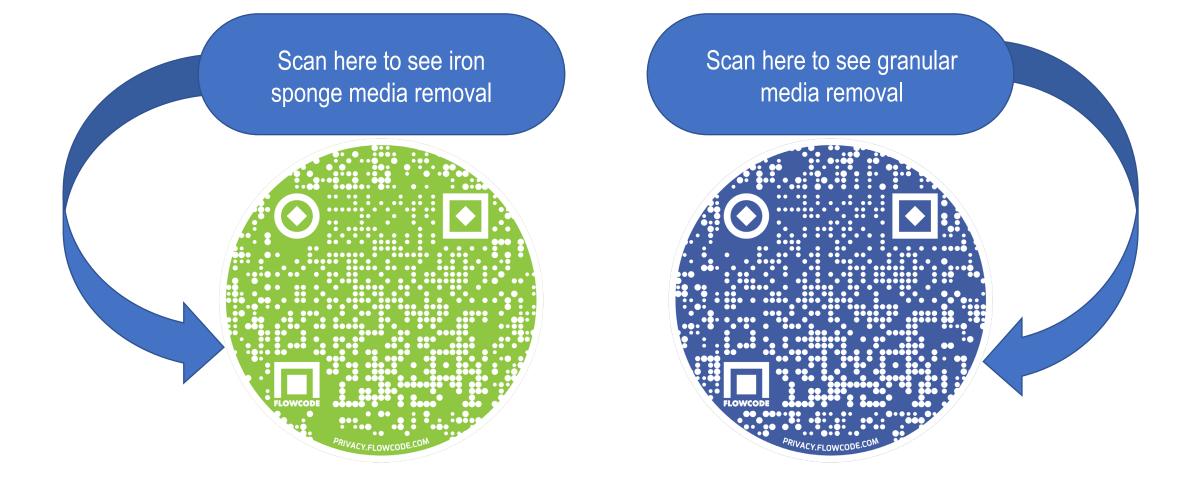
- 40% sulfur loading by weight
- Easy to remove
- Natural product w/out chemical impregnates
- Operating condition requirements for DARCO products are
  - H<sub>2</sub>S: 1 3,000 PPM
  - RH: +60%
  - 02: 4:1 vs. H2S
  - H<sub>2</sub>S removal uses catalytic reaction: BG1 needs 5-7 sec. contact time
  - Temp < 160 degrees F







## Removal of Dry Scrubber Media: Videos



## The Case for Adding $O_2$

#### You Can Add O<sub>2</sub> and Still Meet Pipeline Specs

- Pipeline limits for O<sub>2</sub> typically range from 0.2% (2000 ppm) to 1% (10,000 ppm)
- Adding O<sub>2</sub> (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<sub>2</sub> 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 <sub>2</sub> S 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?

#### **Contact:**

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