CECTI C & D Operator's Short School

Using Pure Oxygen to Prevent H_2S Formation

November 7, 2025

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The Problem

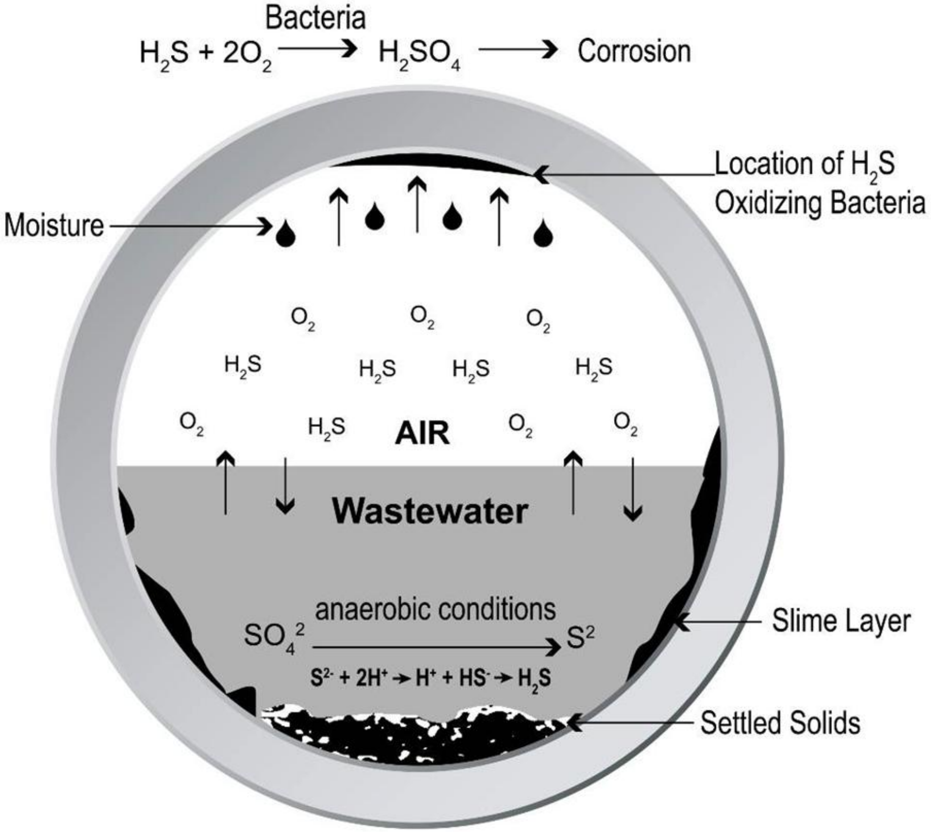
- Some collection systems lack sufficient flow and velocity to keep lines flushed which allows hydrogen sulfide to form

- Hydrogen sulfide (H_2S)
    - Toxic substance that acts as a respiratory depressant
    - Probably the most difficult compound plaguing wastewater collection systems today

- Hydrogen sulfide raises two primary concerns:
    - Nuisance complaints from odor emissions
    - Corrosion to steel and concrete structures

The Problem

- Hydrogen sulfide is generated by sulfate-reducing bacteria in the biofilm of the aqueous phase, under anaerobic conditions.
- It is then emitted from the water and ascends into the biofilm on the unwetted, upper pipe wall where sulfur-oxidizing bacteria accumulate.
- The sulfur-oxidizing bacteria convert hydrogen sulfide to sulfuric acid which attacks the calcium carbonate in concrete and steel components.



Key Points to the Solution

- Dangers of H_2S
- Treatment Options
- Benefits of Pure Oxygen Infusion
- Designing an Oxygen Infusion System

Dangers of H_2S Exposure

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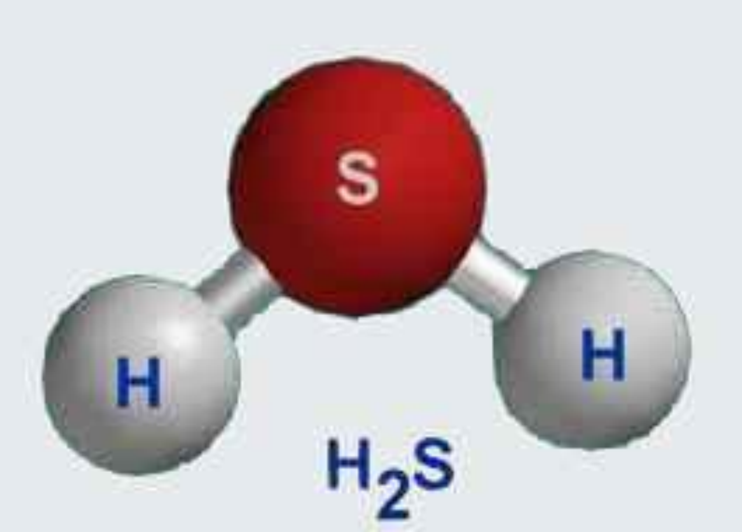
Signs of Short-Term Exposure to H_2S Gas

- Eye Irritation
- Headache
- Loss of appetite
- Irritability
- Breathing issues
- Diarrhea
- Nausea
- Vomiting
- Insomnia
- Fatigue



- Repeated exposure (even below 10 ppm) can cause symptoms to increase at lower doses

Reactions to H_2S Gas Exposure at Varying Concentrations

Concentration (ppm)	Reaction
0.00011 – 0.00033	Typical background concentration
0.01 – 1.5	Odor threshold. Odor becomes offensive at 3-5 ppm
2 – 5	Prolonged exposure may cause nausea, tearing of eyes, headaches, loss of sleep, airway problems
20	Possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness
> 30	Odor described as sweet or sickening smell
50 – 100	Exposure will cause conjunctivitis and respiratory tract irritation after 1 hour. Also causes loss of appetite and upset stomach
> 100	Immediately dangerous to life and health (IDLH). Exposure at 100 ppm will cause cough, loss of smell and eye irritation between 2 and 15 minutes. Between 15 and 30 minutes of exposure will cause altered breathing and drowsiness. After 1 hour of exposure, you will have throat irritation and the severity of symptoms will increase over time. Can cause death after around 48 hours.
100 – 150	Complete loss of smell
500 – 700	Exposure will cause staggering and collapsing after only 5 minutes. You will have serious damage to eyes after 30 minutes and death between 30 and 60 minutes
700 – 1,000	Exposure will cause immediate collapse and unconsciousness after 1-2 breaths. You will then stop breathing altogether and will die within minutes
1,000 – 2,000	Exposure will cause instant death

H_2S Exposure Limits

NIOSH Recommended Exposure Limit	10 ppm
OSHA General Industry Ceiling	20 ppm
OSHA General Peak Limit	50 ppm for up to 10 minutes with no other exposure during shift
NIOSH IDLH	100 ppm

First Aid for H_2S Exposure

Eye Exposure	Skin Exposure	Breathing	Rescue
• Do not wear contacts where exposure is possible. • Rinse with large amounts of water. • If irritation persists, seek medical attention.	• If liquid H_2S contacts skin, immediately flush with water. Remove any contaminated clothing. • If irritation persists, seek medical attention.	• Move to fresh air immediately. • Perform artificial respiration if breathing has stopped. • Get medical attention immediately.	• Do not attempt. • Contact authorities and follow site instructions.

Treatment Options

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Preventing Odor and Corrosion

Possible Chemicals to Control Collection System Odors

Chemical	Dose (Gal/Lb Sulfide)	Cost ($/Gal)
Bioxide	0.87	$2.83
Calcium Nitrate (50% $CaNO_3$ Solution)	0.78	$2.95
Ferrous Chloride (30% $FeCl_2$ Solution)	1.31	$2.39
Ferric Chloride (30% $FeCl_3$ Solution)	1.14	$2.15
Hydrogen Peroxide (50% H_2O_2 Solution)	2.40	$3.00
Potassium Permanganate (3% $KMnO_4$ Solution)	0.59	$22.13
Sodium Hypochlorite (12.5% NaClO Solution)	3.20	$1.00

Some chemicals treat the symptoms only

Benefits of Pure Oxygen Infusion

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Benefit of Pure Oxygen

- Prevents H_2S formation (and H_2SO_4 corrosion)
- No onsite storage of chemicals
- May be generated on site or fed from a LOX system
- Easily controllable based on ORP readings
- Reduces bioload entering plant lowering aeration requirements
- Relatively fast reaction

Using Pure Oxygen for Odor Control and Corrosion Prevention

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Design Considerations

Designing Oxygen Injection Equipment for Odor and Corrosion Control

- There are two key questions that must be considered when designing an oxygen injection system for odor and corrosion control

  - How much oxygen is needed? Quantity.

  - Where should it be injected? Location.

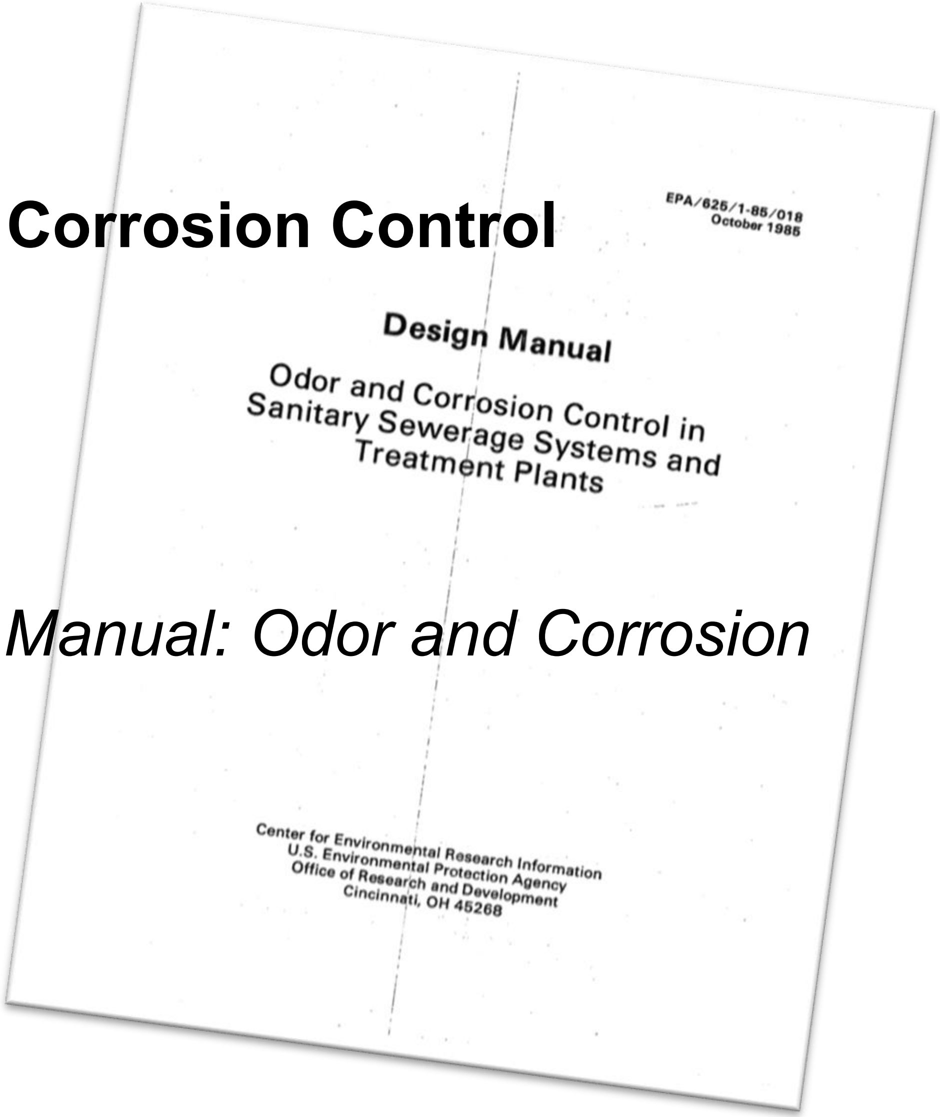
Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Estimating Oxygen Quantity

  - Total $O_2 = O_{2OUR} + O_{2S2}$

  - *Based on methods outlined in EPA's Design Manual: Odor and Corrosion Control in Sanitary Sewerage*



Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Oxygen Uptake Rate (OUR)

    - OUR is a measure of microbiology oxygen consumption within the wastewater.

    - OUR must be satisfied to maintain aerobic conditions within the pipeline.

    - OUR varies with temperature and wastewater quality (COD/BOD).

Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Oxygen Uptake Rate (OUR)
    - OUR ranges from 5 to 15-mg/L/hr for most municipal wastewaters
        - 10-mg/L/hr is typical for design, if information not available
    - Important: Longest HRT should be utilized for OUR calculations, often requires field investigation. Longest HRT is typically at minimum flow.

Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Oxygen Uptake Rate (OUR)

    - $O2_{OUR}$ (lb/d) = OUR (mg/L/hr) * HRT (hrs) * Q (mgd) * 8.34
    - $O2_{OUR}$ (lb/d) = 10 (mg/L/hr) * 2.5 (hrs) * 15 (mgd) * 8.34
    - $O2_{OUR}$ (lb/d) = 3,128

- Note: DO concentration to satisfy oxygen uptake rate is OUR * HRT. In example above, the DO concentration needed at injection site is 25-mg/L.

Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Sulfide Oxidation (S2)
    - In most cases, sulfides have already formed upstream of oxygen injection.
        - Dissolved free sulfides (H_2S, HS^- and S_2^-)
    - S2 must be satisfied to oxidize existing sulfides to prevent possible odor or corrosion concerns.
    - S2 varies with temperature and wastewater quality, specifically pH.

Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Sulfide Oxidation (S2)
    - Theoretically, O_2:S2 ratio is 2 : 1
    - Due to competing reactions, 5:1 is typically used for design
    - Important: S2 requirements will be maximum when flow is maximum - determine variability with flow

Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Sulfide Oxidation (S2)

    - $O2_{S2}$ (lb/d) = S_2 (mg/L) * O_2:S2 * Q (mgd) * 8.34
    - $O2_{S2}$ (lb/d) = 3 (mg/L) * 5 * 15 (mgd) * 8.34
    - $O2_{S2}$ (lb/d) = 1,877

- Note: DO concentration for sulfide oxidation, is S_2 * O_2:S_2. In example above, the DO concentration needed at injection site is 15-mg/L.

Design Considerations

Sizing Oxygen Injection Equipment for Odor and Corrosion Control

- Total $O_2 = O_{2OUR} + O_{2S2}$
    - Total O_2 (lb/d) = 3,128 + 1,877
    - Total O_2 (lb/d) = 5,005
- Note: DO concentration for total O_2 in example is ~40-mg/L.
- Achieving these levels is extremely difficult and inefficient with most conventional aeration technologies.

Design Considerations

Locating Oxygen Injection Equipment for Odor and Corrosion Control

- Location is Dependent on Goals
  - Odor Control
    - Can be located more closely to problem area
  - Corrosion Control
    - Ideally entire pipeline is free of H_2S
    - Can be strategically located

- Requires in-depth knowledge of collection system, diurnal flows, pump operations, etc.
  - Field evaluation studies recommended

Design Considerations

Locating Oxygen Injection Equipment for Odor and Corrosion Control

- Ensure that adequate pressure is available to maintain DO in solution for the time required to be utilized or install multiple systems in series.

- In practice, it takes 15 to 30-min for the sulfide reaction to complete.

Design Considerations

Controlling the Oxygen Dose – Oxidation Reduction Potential (ORP)

- Good indicator of biological activity and electron availability
- Provides tighter process control at low DO levels
- Generally, ORP levels greater than -150mV correspond to minimal activity of sulfate-reducing bacteria, effectively preventing the formation of H_2S

Injecting Pure Oxygen

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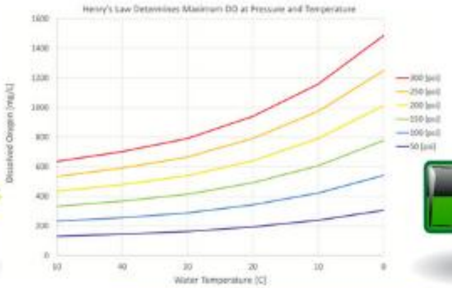
The DGI Process



PRESSURIZE

A slipstream of process water is pressurized to maximize achievable dissolved oxygen.

INFUSE

95%+ saturation of the slipstream with dissolved oxygen is achieved with Fuel Tech's IDGI technology.

INJECT

The pressured stream of oxygenated water is injected into manholes or lift stations.

In validation testing endorsed by leading industry experts, 99%+ of the injected oxygen is transferred to the receiving water and is available for process needs.

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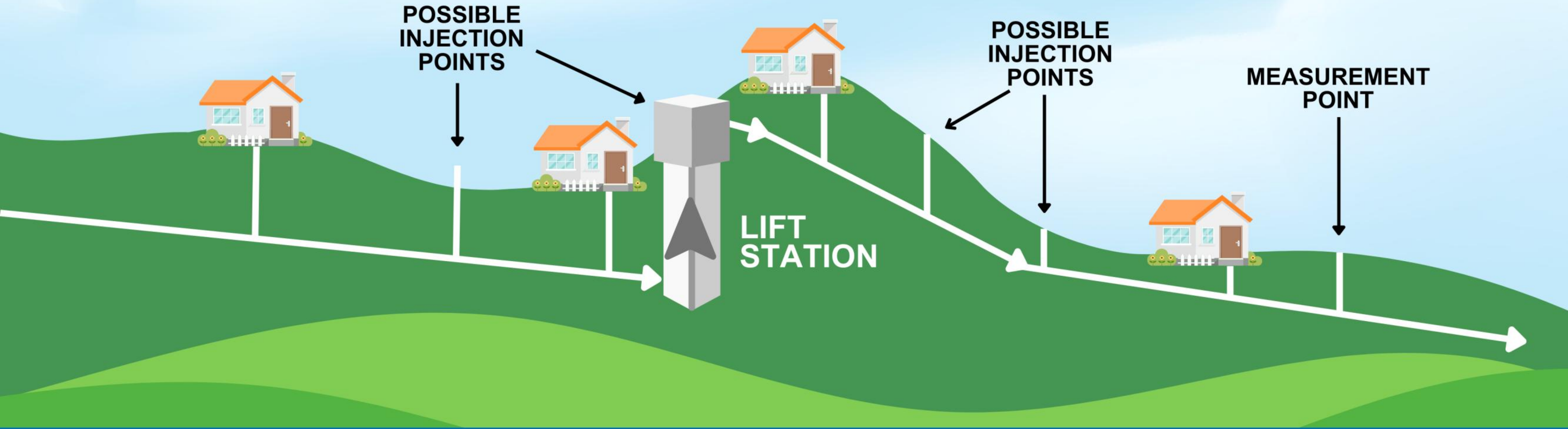
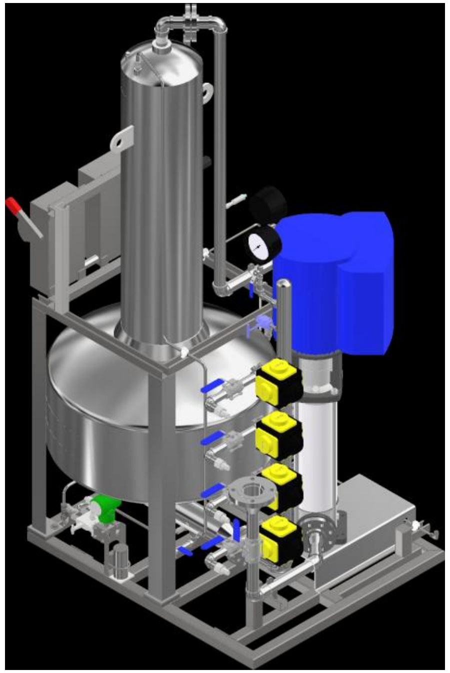
Conventional Gravity System



Oxygen Series



Model		0-2-6	0-4-25	0-6-60	0-8-100	0-12-240
		Oxygen Lbs/day @200 PSI, Water at 1 PPT Salinity				
Standard Oxygen Output	Water Temp. 10˚ C	45	180	406	721	1,822
System Operating Range	Nominal Fluid Flow GPM	7	27	61	108	244
	Operating Pressure PSIG	50-300				
	Ambient Temperature ˚F	40-104				
	Vessel Design	316L Stainless Steel, ASME Section VIII				
	Max. Pressure PSIG	300 PSIG				

Questions

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Thank you

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