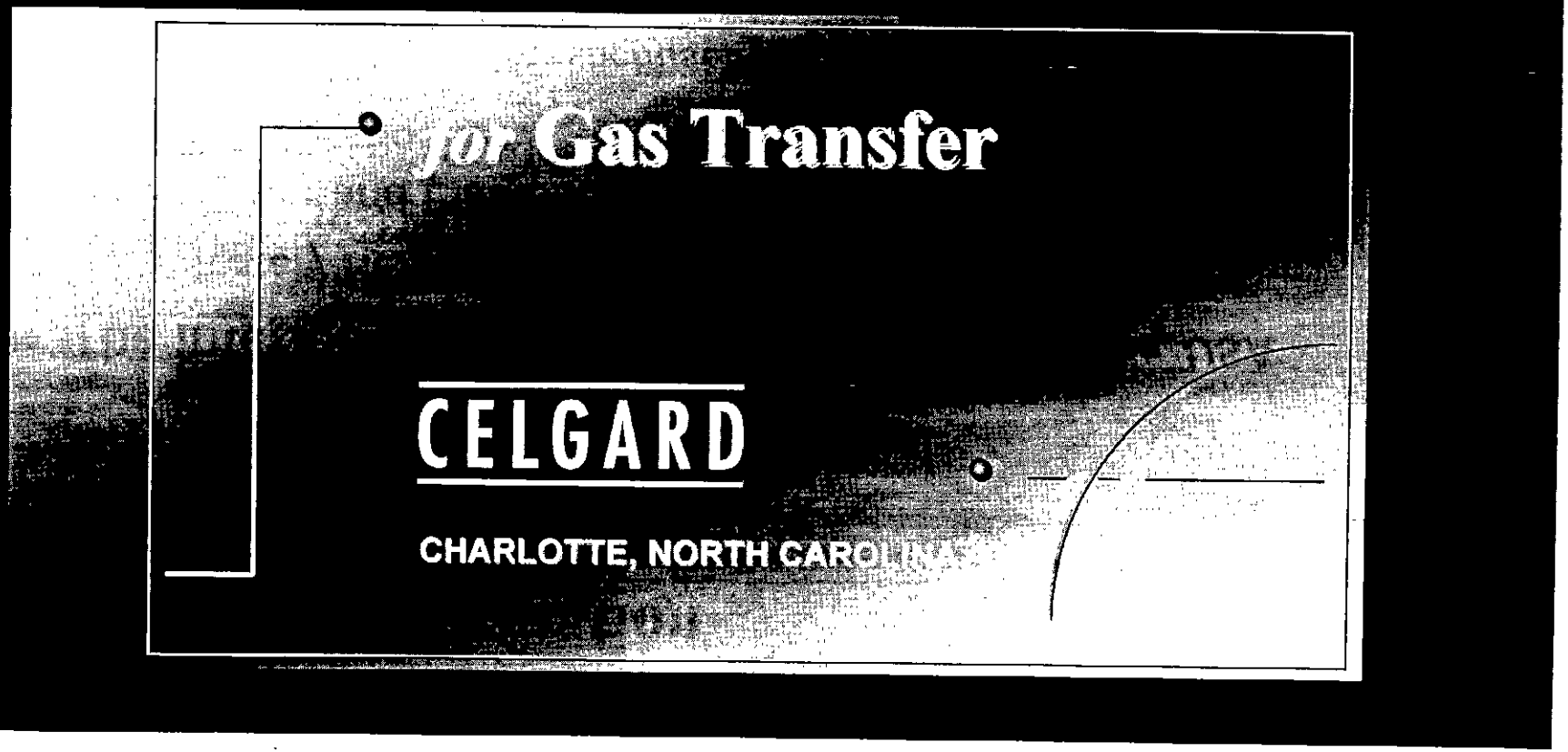
Liqui-Cel®

Extra-Flow Membrane Contactor Technology



Company Information

Liqui-Cel®
Membrane Contactor

- **The Intertech Group**, *Charleston, South Carolina, USA*
  - Privately Held (2nd Largest in SC)
  - Polymer and Elastomeric Films, Structures, and Fiber Composites
  - **Daramic Inc.**, *Massachusetts*
    - World Largest Producer of Lead Acid Battery Separators
    - **Celgard Inc.**, *Charlotte, North Carolina, USA*

Gas-Transfer Systems

- **Microporous Flat Sheet Membrane**
  - **Battery Separators**
    - **Primary and Secondary Lithium**
    - **Ni-Cd**
    - **High Energy Density**
  - **Blood Oxygenation**
- **Fibers and Membrane Contactors**
  - **Microporous Hollow Fiber Membranes**
    - **Blood Oxygenation**
  - **Liqui-Cel® Membrane Contactors**
    - **Degasification/Gas Absorption**

Global Network

Liqui-Cel®
Membrane Contactor

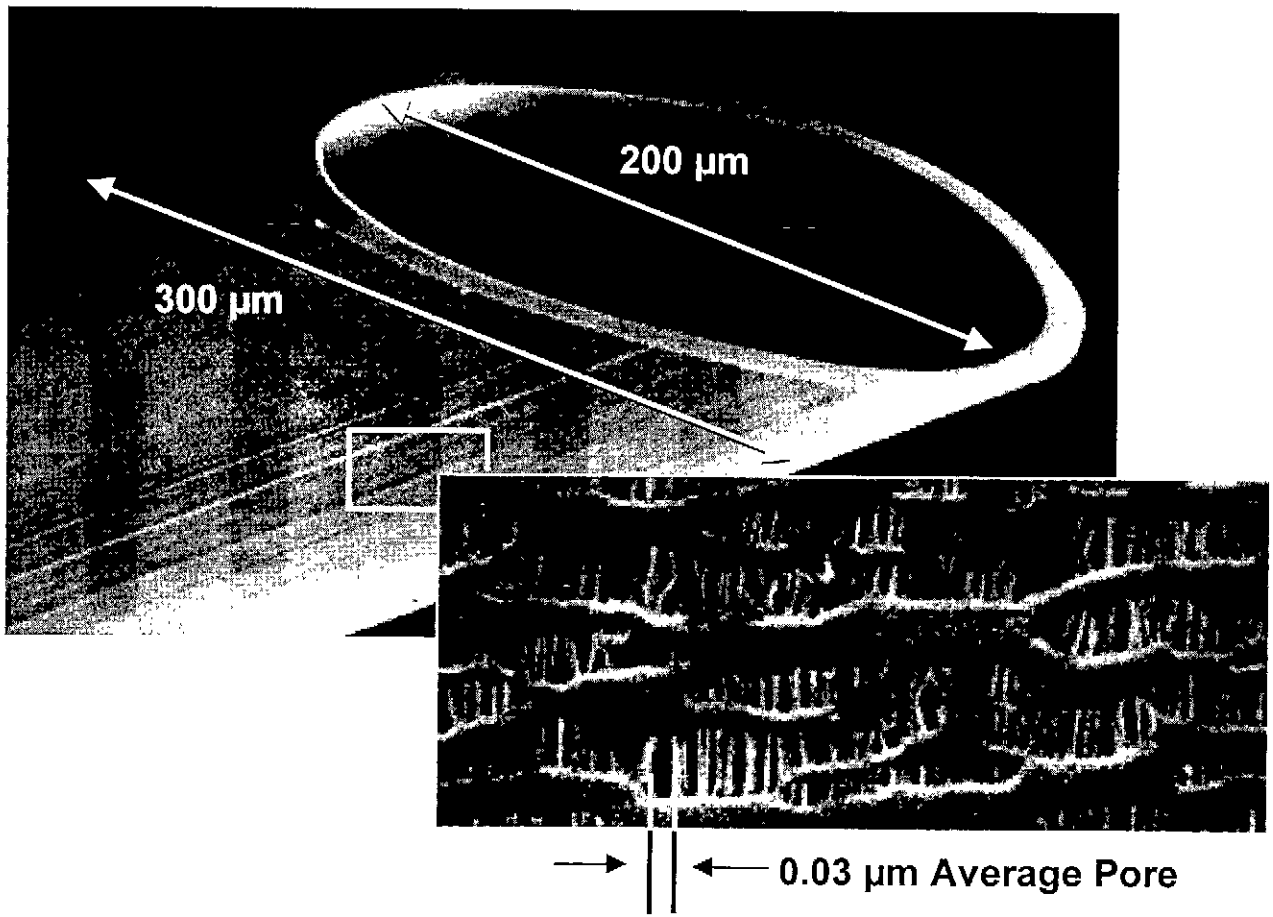
- Headquarted in Charlotte, NC
- Regional Support:
  - Sales and Technical Service Offices
    - China
    - Germany
    - Japan
    - Korea
    - Taiwan

Gas-Transfer-Solutions

SEM of Celgard® Microporous Hollow Fiber Membrane

Liqui-Cel®

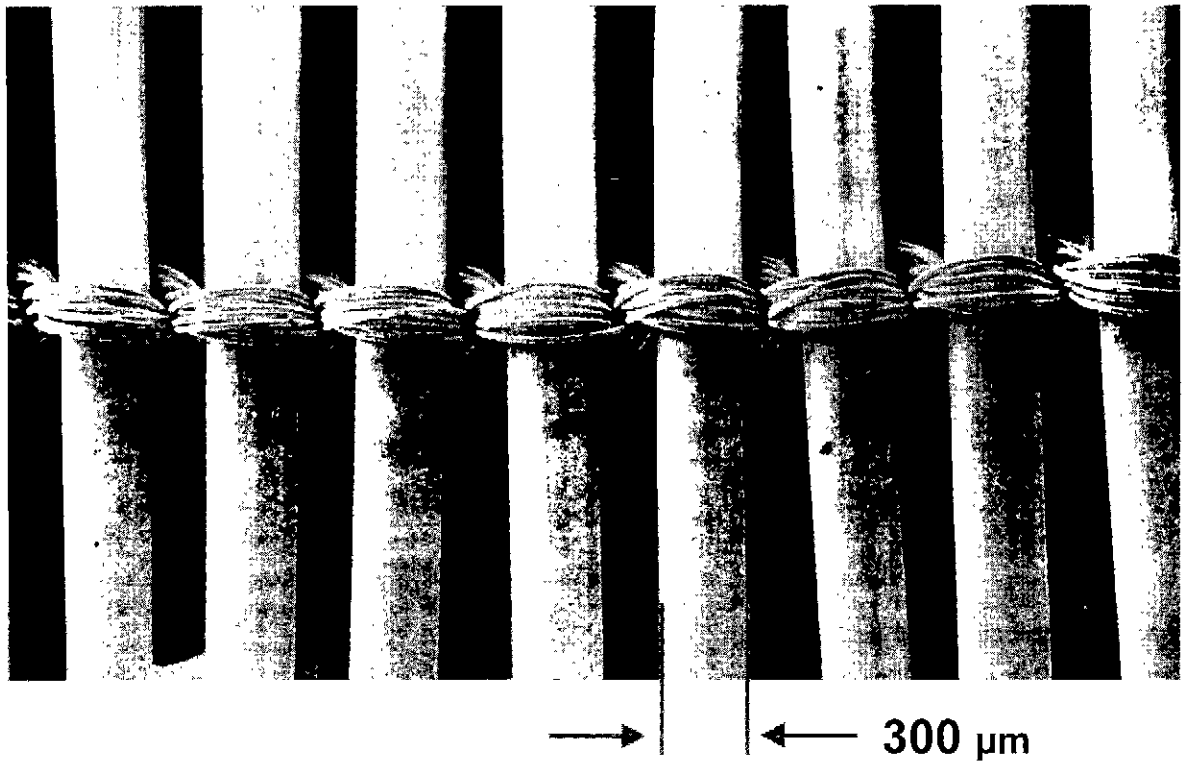
Membrane Contactors



Gas-Transfer-Solutions

Celgard® Microporous Hollow Fiber Array

Liqui-Cel® Membrane Contactor



Gas-Transfer-Solutions

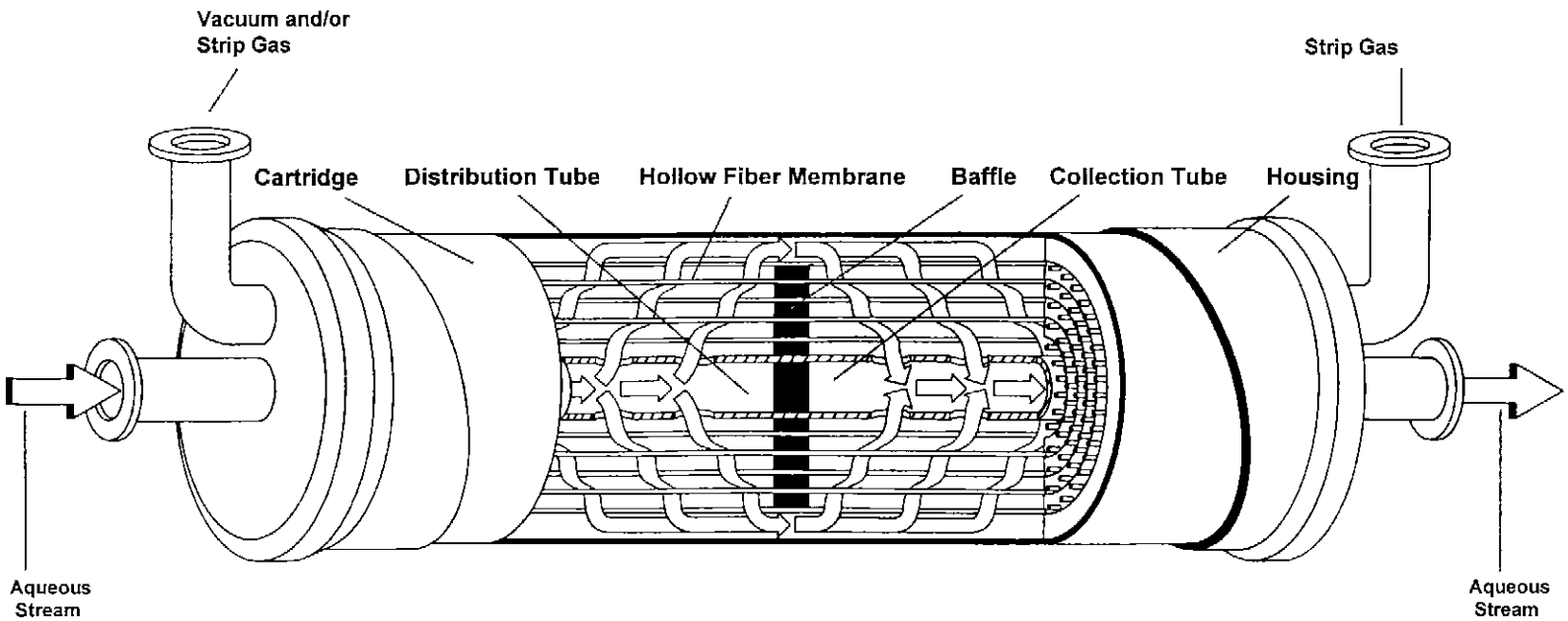
PC-P56UPW2000 6

Liqui-Cel® Extra-Flow Membrane Contactor

Liqui-Cel®

Membrane Contactors

- **Patented Design**
- **FDA Compliant***



* With Appropriate O-Rings

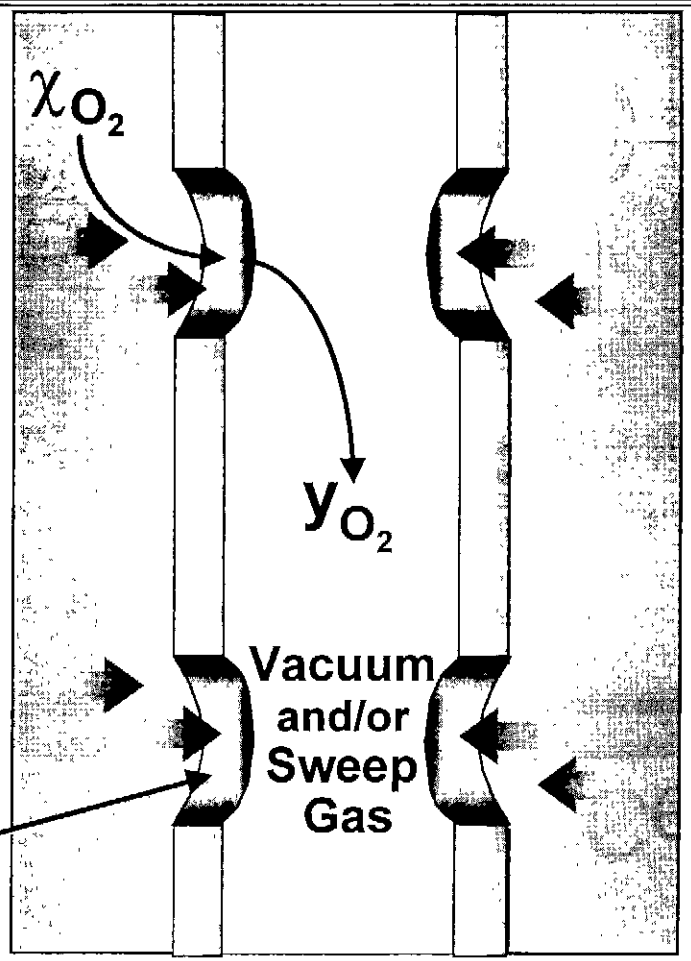
PC-P56UPW2000 7

Principles of Gas Transfer

Liqui-Cel

Membrane Contactor

- Gases in the Atmosphere Dissolve into Water until Equilibrium is Reached
- Equilibrium between the Liquid and Gas Phase Is Offset when a Vacuum and/or Source of Strip Gas is Applied
- This Creates a Driving Force to Move Gases from the Liquid Phase into the Gas Phase



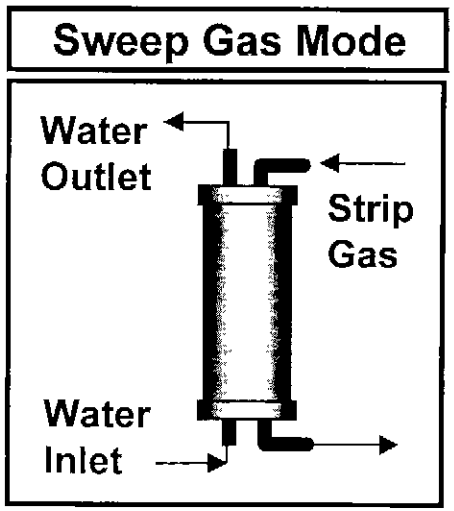
Gas-Transfer

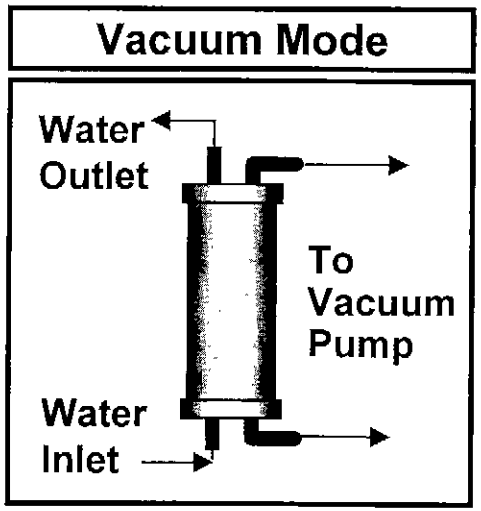
Operating Modes

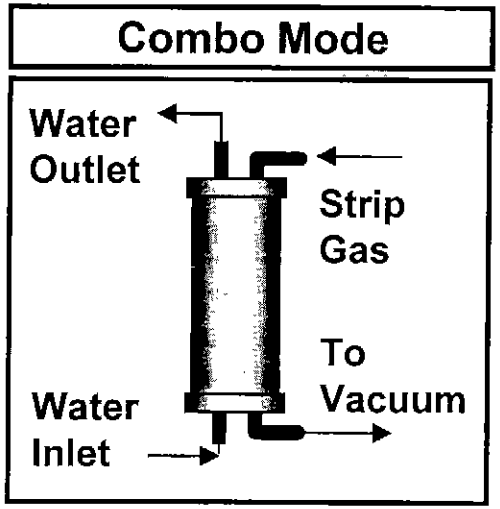
Liqui-Cel

By Changing the partial pressure of the gas we can either remove from or dissolve gas into water.

- Lower the partial pressure, the gas will be removed from the water
- Increase the partial pressure, the gas will dissolve into the water







Why Liqui-Cel Membrane Contactors?

Liqui-Cel®

Membrane Contactor

FEATURES	BENEFITS
Small Size-Ten Times the Surface Area of Conventional Degasifiers	• Compact SkidsCan • Fit Inside of Existing Buildings • Lower Installation Costs
Modular Like other Water Treatment Components	• Can Be Easily Expanded for Increased Flow or Greater Gas Removal
Total Gas Control	• Configurable to Available Space, Build Up and/or Out • Allows for Redundancy with Multiple Contactors • O_2, CO_2 and N_2 Control with One Device

Why Liqui-Cel Membrane Contactors? *(Cont.)*

Liqui-Cel®

Membrane Contactors

FEATURES	BENEFITS
Cleanliness	- No Extractables, Quick to Rinse, Can Be Used anywhere in Water System
Low Pressure Drop	- Can Eliminate or Reduce the Number of Transfer Pumps Required
Performance Can Be Accurately Modeled	- Quick sizing Estimate - Guarantee < 1 ppb for O_2, < 1 ppm for CO_2
Does not Require Chemicals to Operate	- Environmentally Friendly and Safe for Employees
Reliable	- 100% Success Rate in the Field Means Easy Start-up - 5 Years of Successful Installations

Gas-Transfer

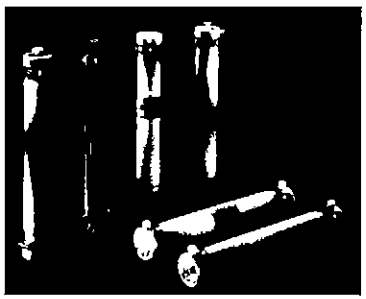
Available Products

Liqui-Cel®

Membrane Contactors

- **2.5-inch Diameter x 8 inch Long Contactor**
  Single Unit Capacity:
  0.5 gpm – 3 gpm (0.1 – 0.7 m^3/h)
  Membrane Area: 15.1 ft^2 (1.4 m^2)
  All Polyolefin Contactor

- **4-inch Diameter x 28 inch Long Contactor**
  Single Unit Capacity:
  5 gpm – 30 gpm (1.1–6.8 m^3/h)
  Membrane Area: 210 ft^2 (19.5 m^2)
  Vessel: Polypropylene, Stainless Steel or PVDF

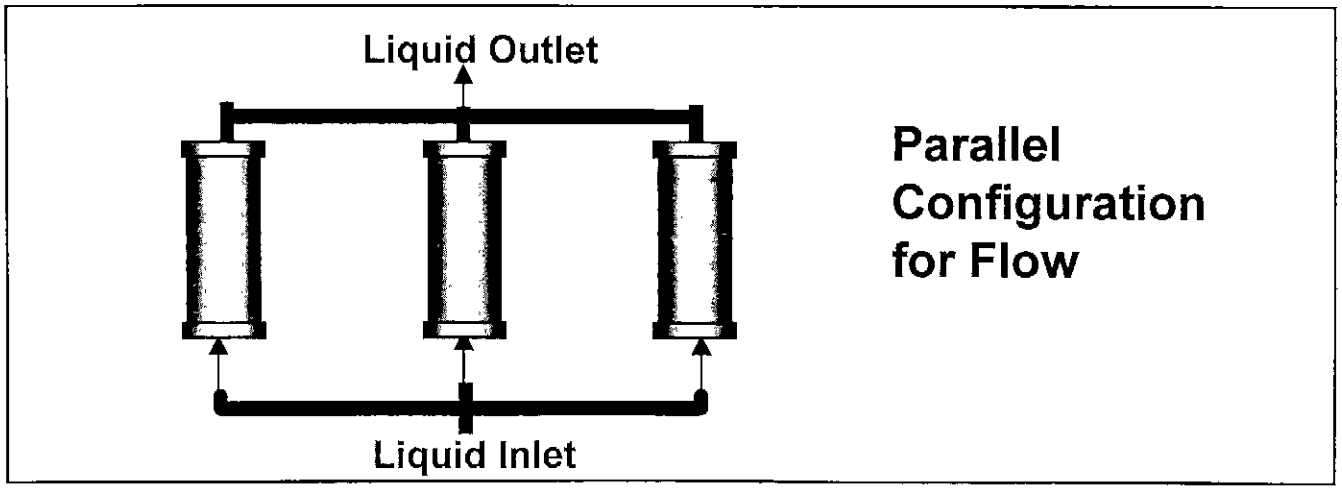


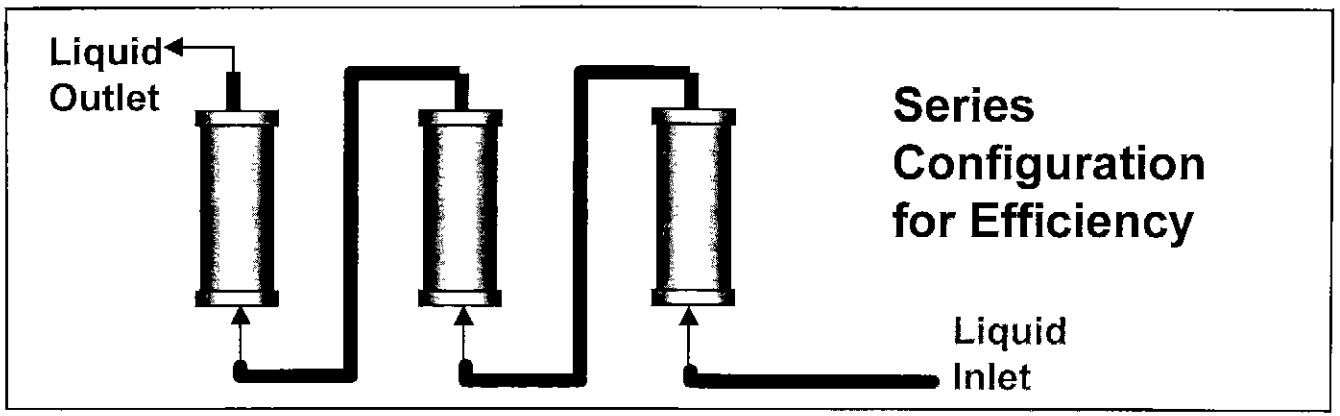
- **10-inch Diameter x 28 inch Long Contactor**
  Single Unit Capacity:
  44 gpm – 210 gpm (10 – 47.7 m^3/h)
  Membrane Area: 1400 ft^2 (130 m^2)
  Vessel: 316 L Stainless Steel or Plastic
  with PVDF inner surface

Gas-Transfer Solutions

System Design Considerations

Liqui-Cel®



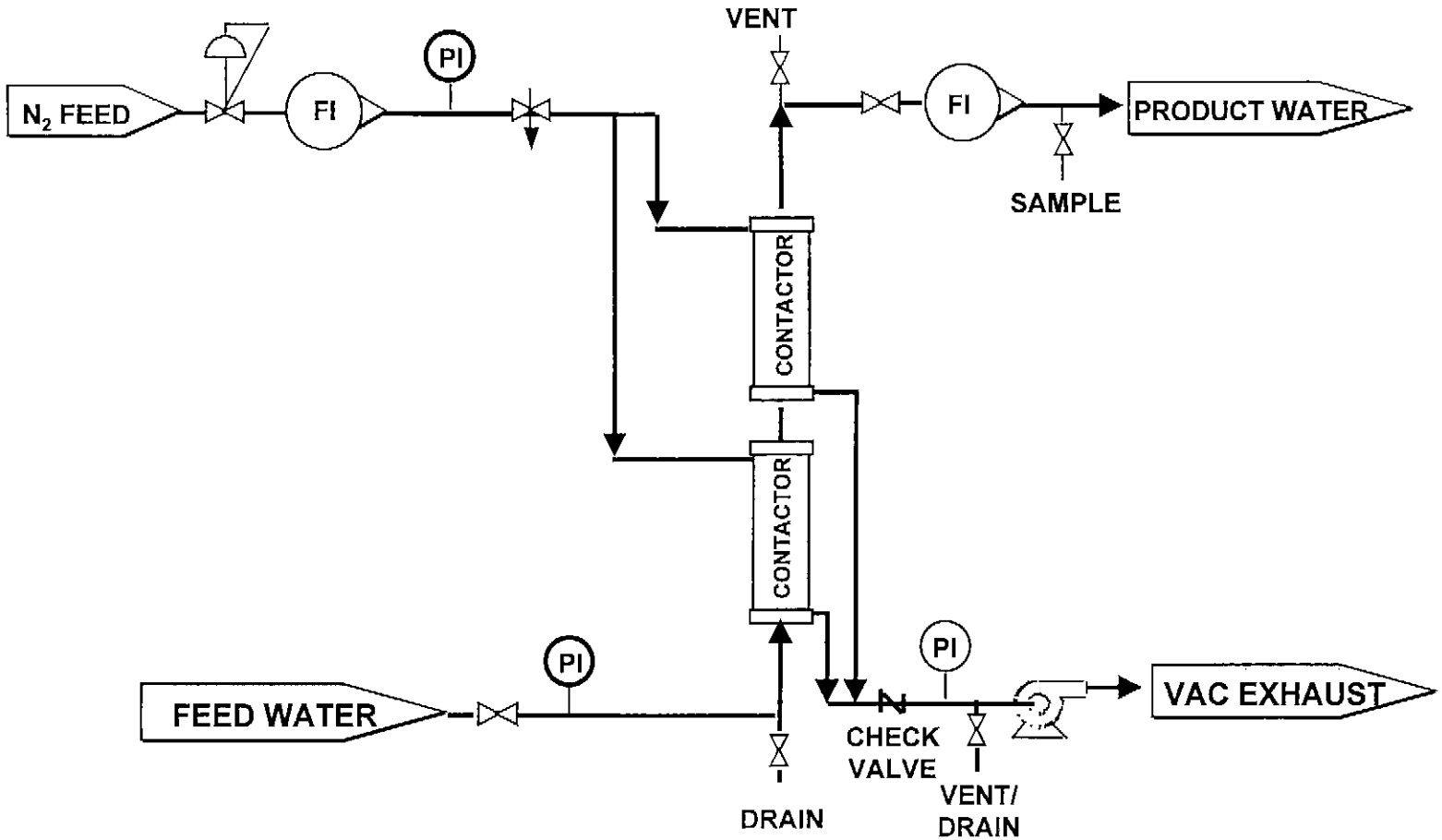


PC-P56UPW2000 13

Gas-Transfer Solutions

Schematic Using Nitrogen and Vacuum Combination

Liqui-Cel®



Gas-Transfer

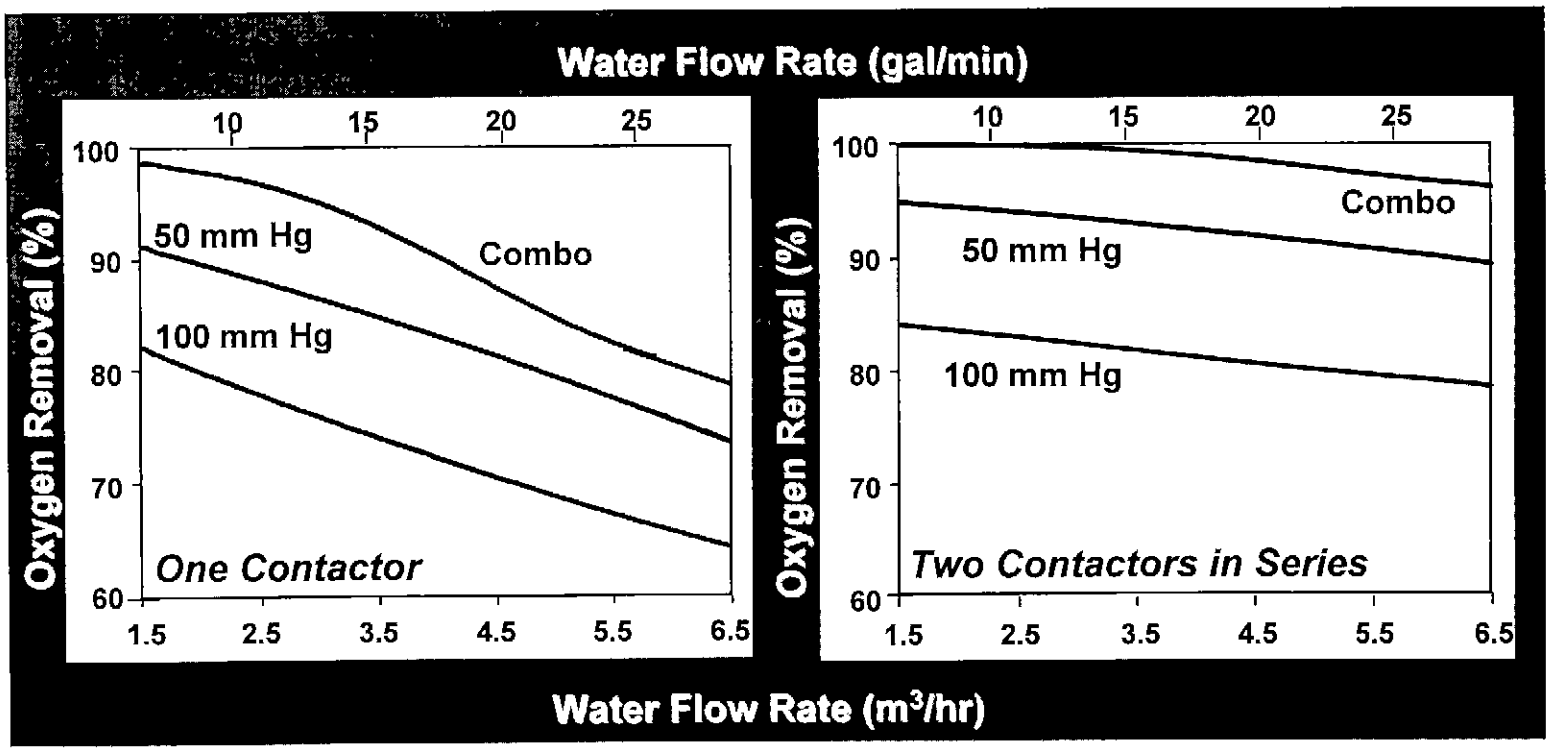
PC-P56UPW2000 14

O_2 Removal Performance

Liqui-Cel

Membrane Contactor

of Liqui-Cel 4×28 Membrane Contactor with X40 Fiber



Temperature 20°C

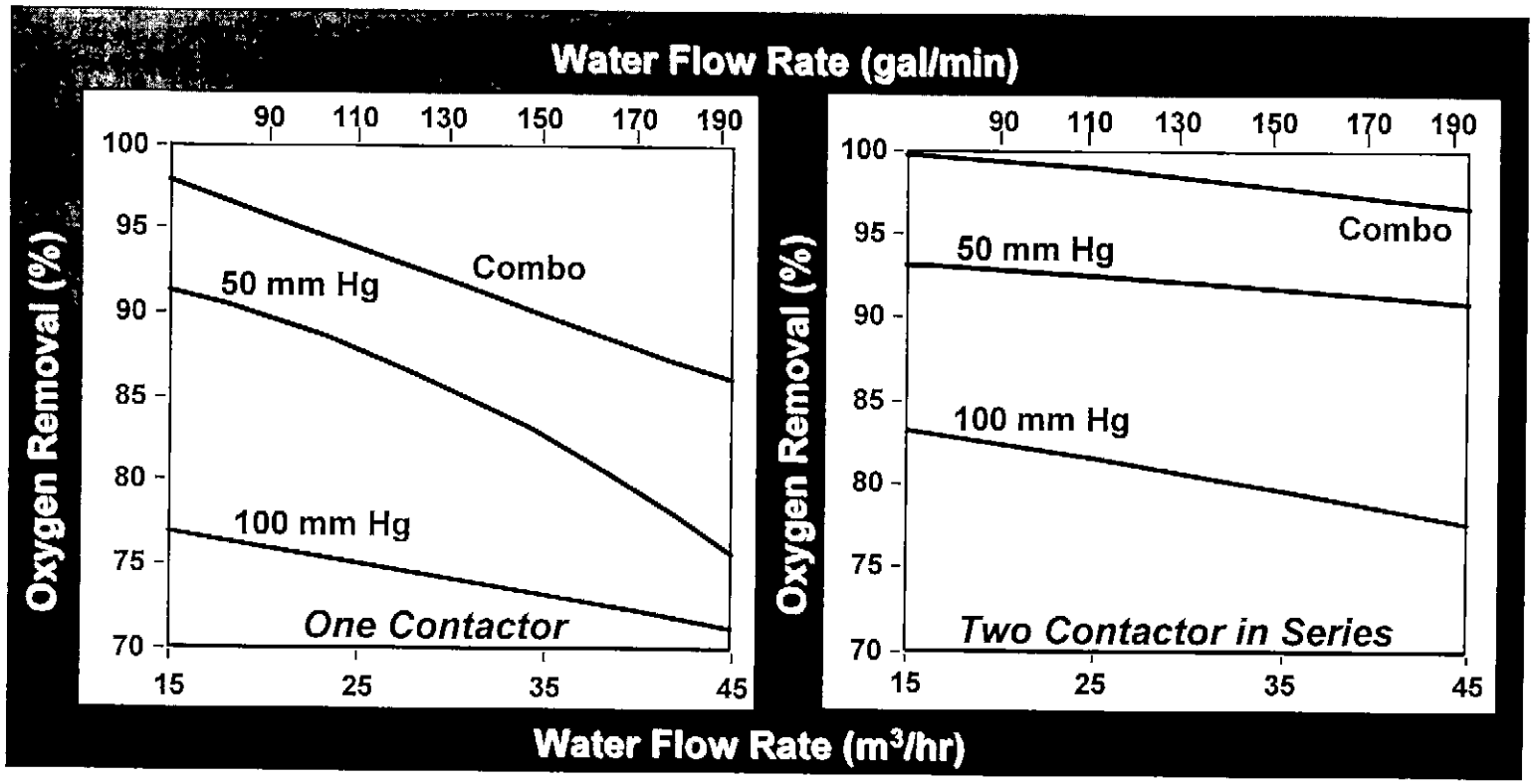
PC-P56UPW2000 15

O_2 Removal Performance

Liqui-Cel®

Membrane Contactor

of Liqui-Cel 10×28 Membrane Contactor with X40 Fiber



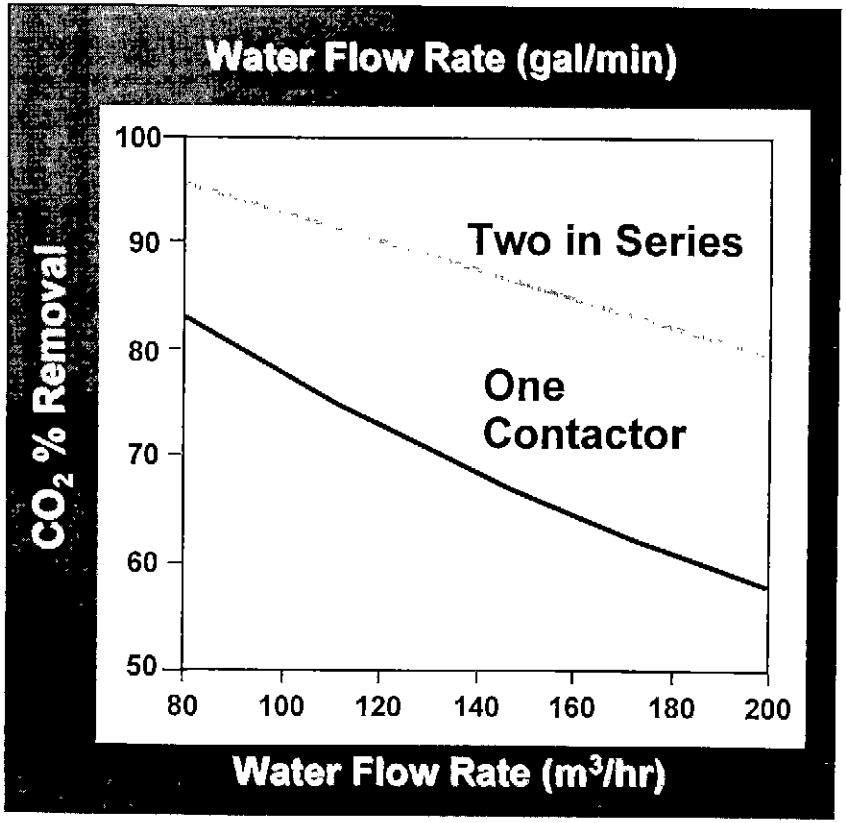
Temperature 20°C

PC-PS6UPW2000 16

Removal Efficiency of Free CO_2

Liqui-Cel

of Liqui-Cel 10×28 Membrane Contactor with X30 Fiber



Conditions

- Temperature = 25°C
- Flow = 25 scfm (40.25 m^3/hr) Air per Contactor
- Sweep Mode
- pH = 4
- CO_2 = 50 ppm Inlet

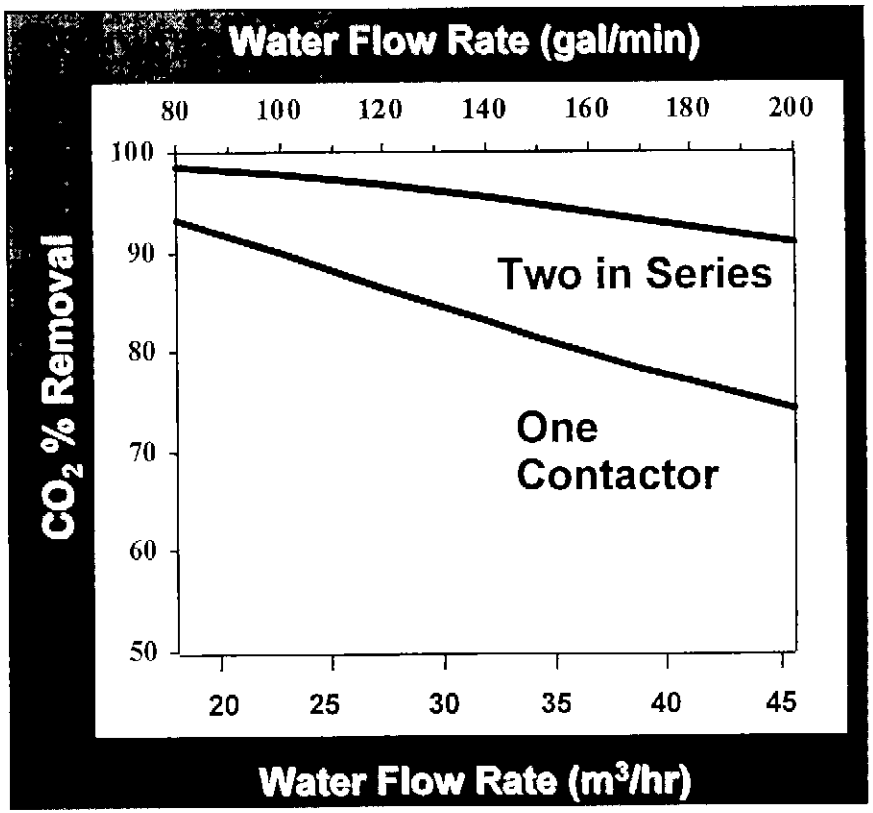
Gas-Transfer Solutions

Removal Efficiency of Free CO_2

Liqui-Cel

Membrane Contactor

of Liqui-Cel 10×28 Membrane Contactor with X30 Fiber



Conditions

- Temperature = 25°C
- Flow = 25 scfm (40.25 m3/hr) Air per Contactor
- Sweep Mode
- pH = 4
- CO2 = 50 ppm Inlet

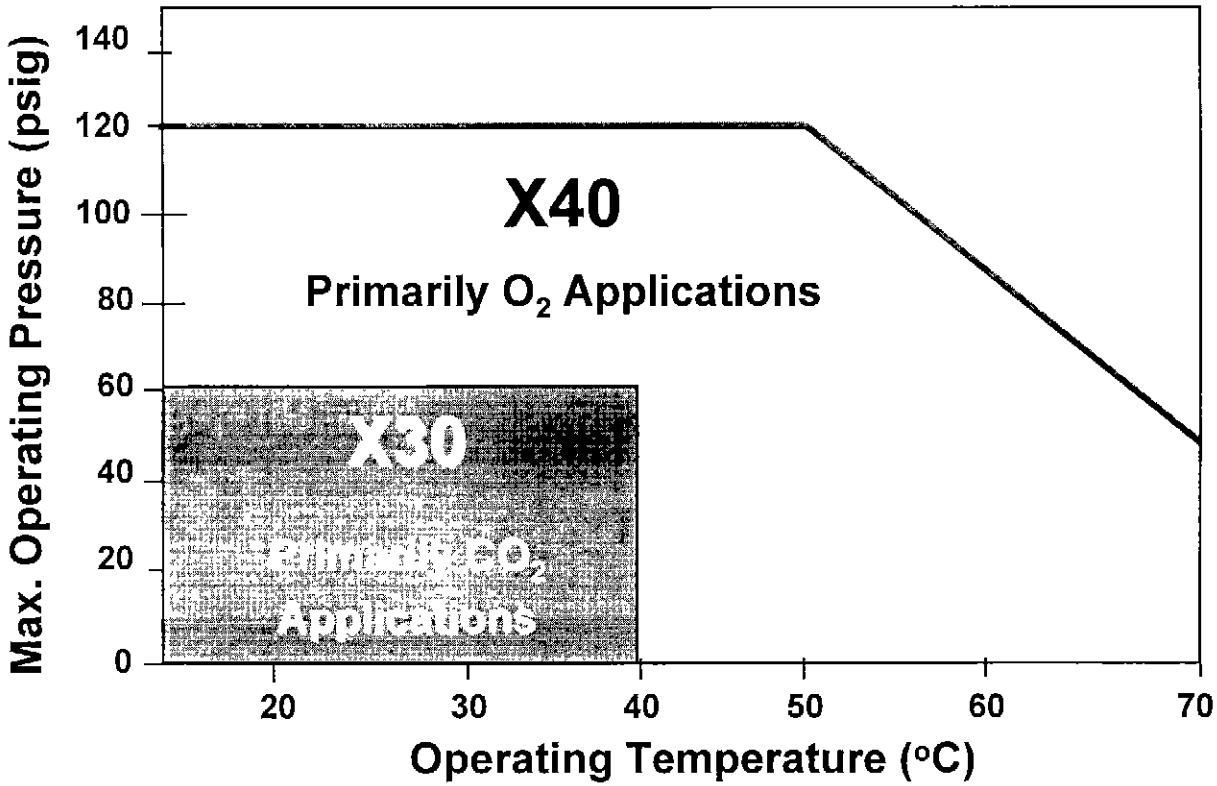
Gas-Transfer

PC-P56UPW2000 18

Operating Pressure & Temperature

Liqui-Cel® Membrane Contactors

for Celgard® Hollow Fiber Membranes



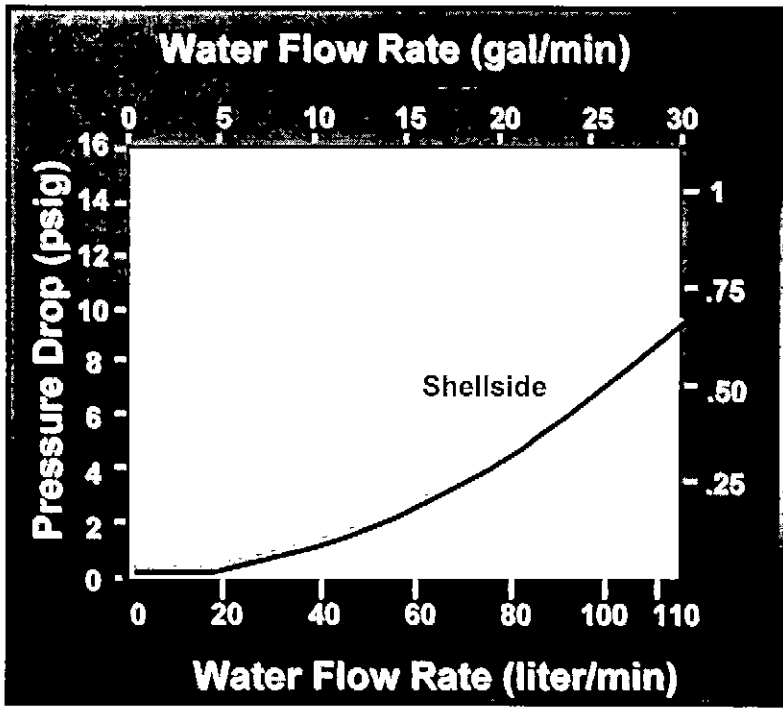
For combo mode: Reduce pressure by 14.7 psig

Gas-Transfer

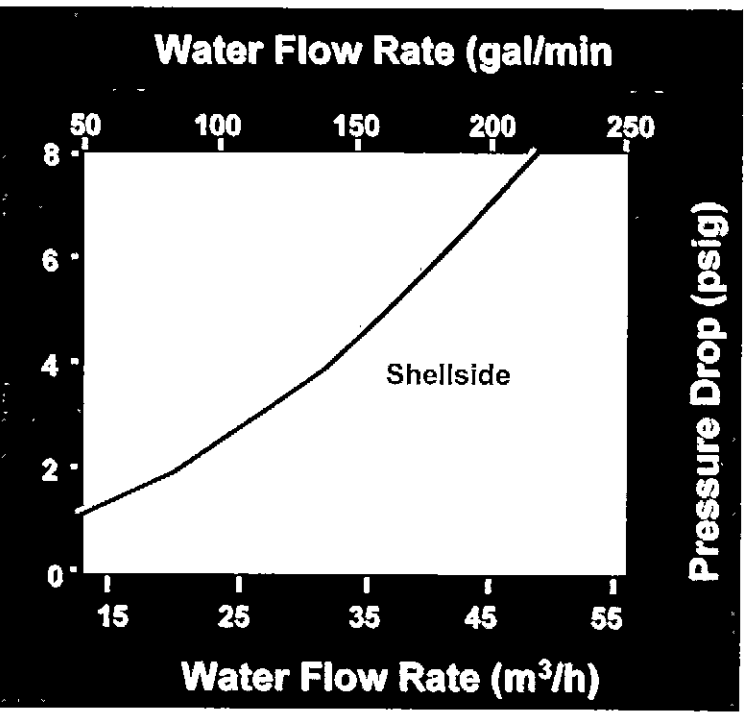
Pressure Drop through Liqui-Cel Membrane Contactors

Liqui-Cel®

4×8 Contactor



10×28 Contactor



PC-P56UPW2000 20

Extractable Information

Liqui-Cel®

4×28, PP Housing, Kalrez® O-Rings, 5.0 gpm Flow Rate.

Parameter	Median Background	Time to Reach Background
TOC, ppb	1.34	35 Minutes
Resistivity, Megohm-cm	18.2	11.5 Hours
Particle, #/mL>= 0.1	0.79	1.35 Hours
There was no indication of Metallic or Ion Extraction in Samples Analyzed by IC, ICP-MS, and GFASS.		

Gas-Transfer-Solutions

Applications for Liqui-Cel Membrane Systems

Liqui-Cel®

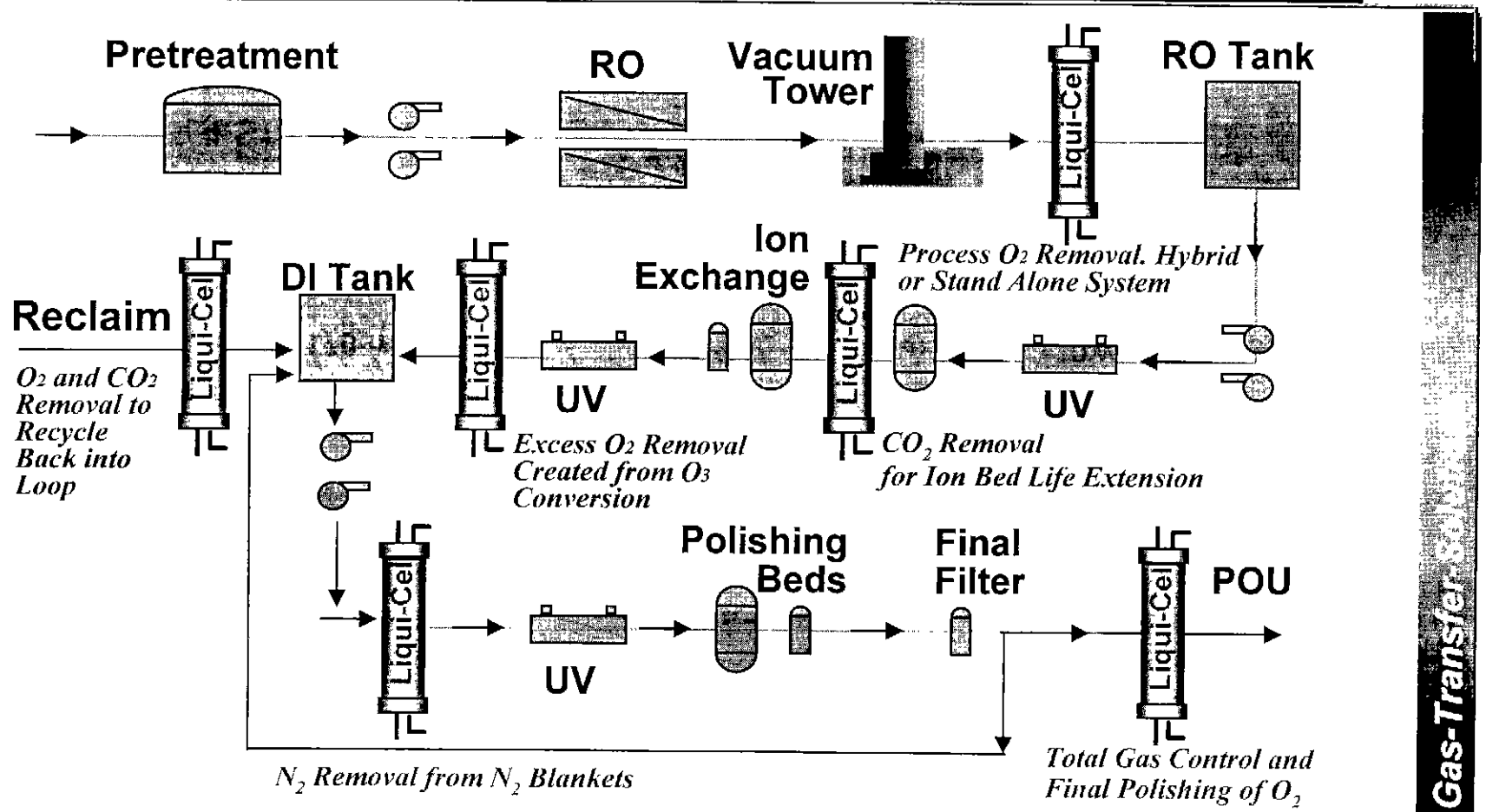
Membrane Contactor

- Removal of Dissolved Oxygen in Electronics Industry at Point of Use and at Central Locations
- Removal of Bulk Oxygen and Nitrogen in the Make-Up System
- Removal of Dissolved Oxygen Formed from Ozone Destruction
- Removal of Dissolved Nitrogen Due to Nitrogen Blankets on Storage Tanks
- Removal of Carbon Dioxide to Extend the Life of Ion Exchange Beds
- CO_2 Removal to Enhance Performance of EDI/CDI Technology
- Accurate Total Control of Dissolved Gases at Point of Use
- Removal of VOC's from Liquids
- Carbonation, Decarbonation and Nitrogenation in the Beverage Industry

Gas-Transfer

Possible Degasification Points in a UPW System

Liqui-Cel



PC-P56UPW2000 23

Gas-Transfer

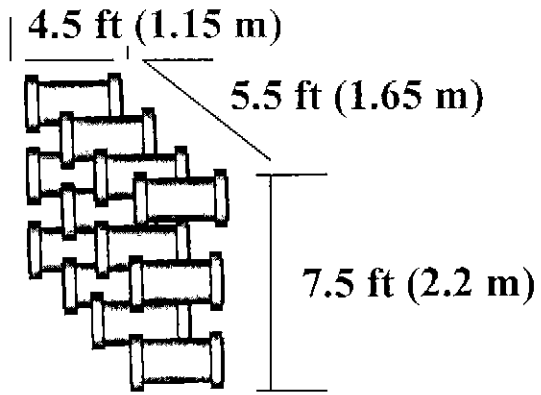
Deoxygenation System Size Comparison

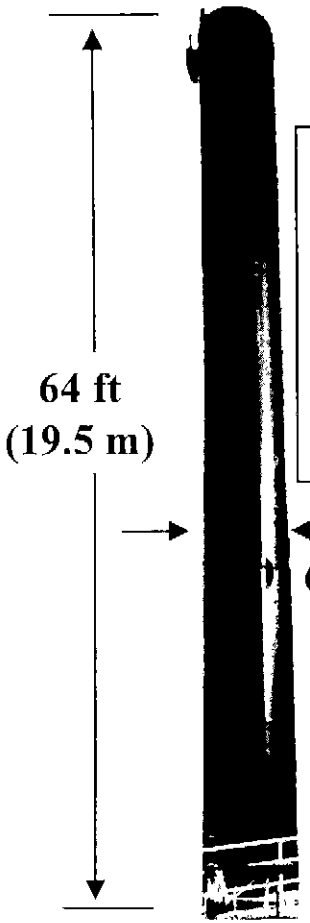
Liqui-Cel

Membrane Contactor

Liqui-Cel® Contactor System (Horizontally Mounted):

Flow	=	748 gpm 170 m^3/hr
Inlet	=	Saturated
Outlet	=	30 ppb





Vacuum Tower System

Flow	=	748 gpm (170 m^3/hr)
Inlet	=	Saturated
Outlet	=	30 ppb

Gas-Transfer

PC-P56UPW2000 24

Partial System Installation List

Liqui-Cel®

Membrane Contactor

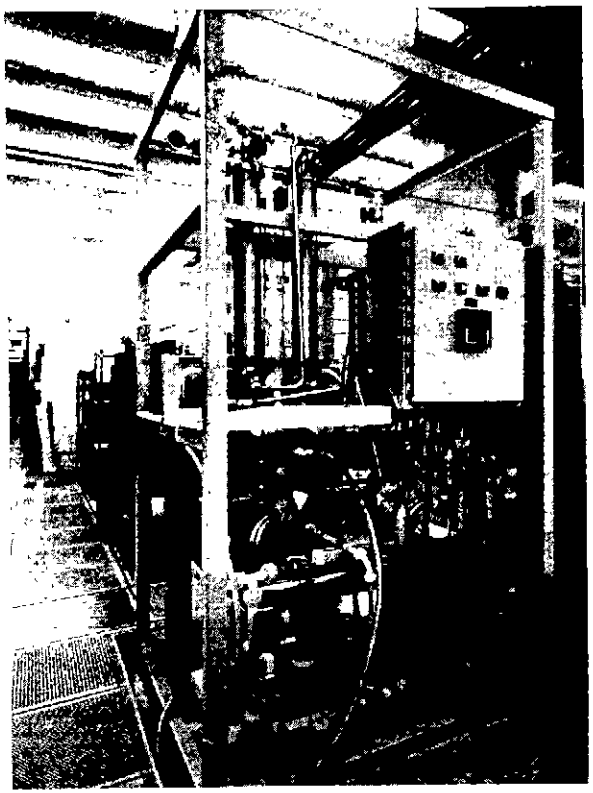
Market	Region	Flow Rate (GPM)	Flow Rate (m^3/hr)	Contactor Size	Application	Mode	Inlet	Outlet Guarantee
Industrial	Europe	110	25	[illegible]	O_2 removal	Combo	9.3ppm	[illegible]
Microelectronics	Europe	286	65	[illegible]	O_2 removal	Combo	200ppb	[illegible]
Power (> 30 systems)	Global	100-800	23-182	[illegible]	O_2 removal/Decarb	Combo	Saturated	
Power	North America	300	68	[illegible]	O_2 removal/Decarb	Combo	Saturated	[illegible]
Beverage-Utilities	North America	150	34	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Asia	1425	324	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Europe	246	56	[illegible]	O_2 removal	Combo		[illegible]
Microelectronics	North America	600	136	[illegible]	O_2 removal	Combo		[illegible]
Photographic Processing	North America	36 gpm 2 systems	8	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	North America	2500	568	[illegible]	Decarb/O_2 removal	Combo	Saturated	[illegible]
Microelectronics	North America	1800	409	[illegible]	Decarb/O_2 removal	Combo	Saturated	[illegible]
Microelectronics	North America	1500	341	[illegible]	O_2 removal	Combo	Saturated	
Microelectronics	Asia	84	19	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Europe	264	60	[illegible]	O_2 removal	Combo	8000ppb	[illegible]
Microelectronics	Asia	242	55	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Asia	352	80	[illegible]	Decarb/O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Asia	1012	230	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Beverage	Asia	89	20	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Asia	62	14	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	Asia	108	25	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	North America	200	45	[illegible]	O_2 removal	Combo	Saturated	[illegible]
Microelectronics	North America	640	145	[illegible]	O_2 removal	Combo	Saturated	[illegible]

Gas-Transfer Solutions

AT&T Ultrapure Water Deoxygenation System

Liqui-Cel

Membrane Contactor



- Sematech Sponsored

Design Basis:

10 gpm (2.30 m^3/hr)

77°F (25°C)

Inlet O_2 Saturated (8.5 ppm)

System Design:

Two 4×28 Contactors in Series

N_2 Sweep – 1.0 scfm (1.6 m^3/hr) per Contactor

Outlet Achieved:

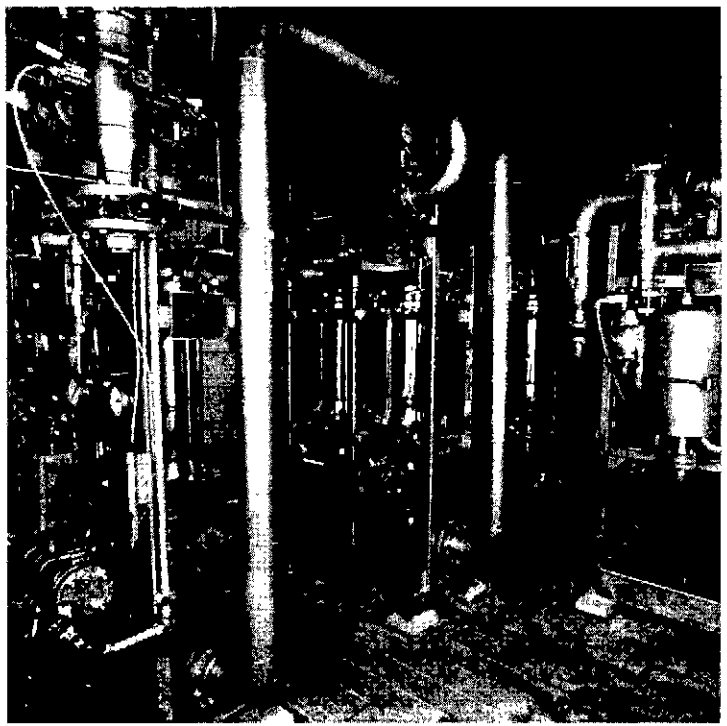
< 15 ppb Dissolved O_2

Gas-Transfer

Lucent Technologies Deoxygenation System

Liqui-Cel®

Membrane Contactor



Design Basis:

250 gpm	(57 m^3/hr)
77°F	(25°C)
Inlet O_2	(4 – 5 ppm)

System Design:

Two Trains of Three 10×28 Contactors in Series

316L SS Housings with 10 RA Finish

Footprint: 14 × 4.5 × 7.5 feet (4.25 × 1.37 × 2.25 m)

27.4 in. Hg Vacuum (64 mm Hg)

N_2 Sweep – 1.9 scfm (3.0 m^3/hr)

Outlet Achieved:

< 10 ppb Dissolved O_2

Gas-Transfer Solutions

Central UPW Deoxygenation System

Liqui-Cel®

Membrane Contactor

Design Basis:

320 gpm (57 m^3/hr)
70°F (21°C)
Inlet O_2 (2.0 ppm)

System Design:

Three Trains of Three 10×28 Contactors in Series

Nine 10×28 Contactors Expandable to 16 Contactors

316L SS Housings with 10 RA Finish

27.4 in. Hg Vacuum (64 mm Hg)

N_2 Sweep – 7.2 scfm (11.6 m^3/hr)

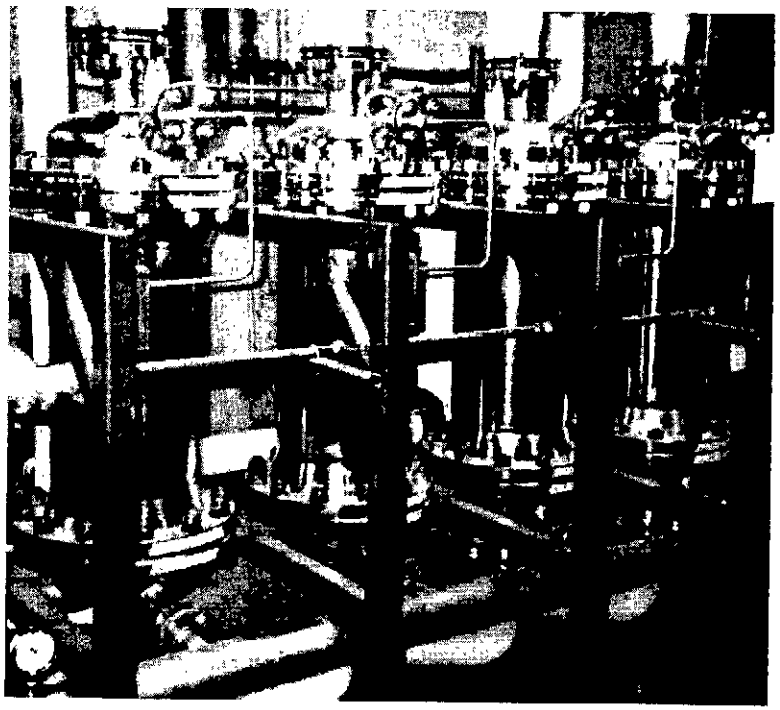
Outlet Achieved:

< 2 ppb Dissolved O_2

Gas-Transfer

Central UPW Deoxygenation System

Liqui-Cel® Membrane Contactors



Design Basis:

200 gpm (45 m^3/hr)

72°F (22°C)

Inlet O_2 Saturated (8.9 ppm)

System Design:

One Train of Four 10×28 Contactors in Series

316 L SS Housings with 25 RA Finish

27 in. Hg Vacuum (74 mm Hg Vacuum)

N_2 Sweep – 1.6 scfm (2.60 m^3/hr)

Outlet Achieved:

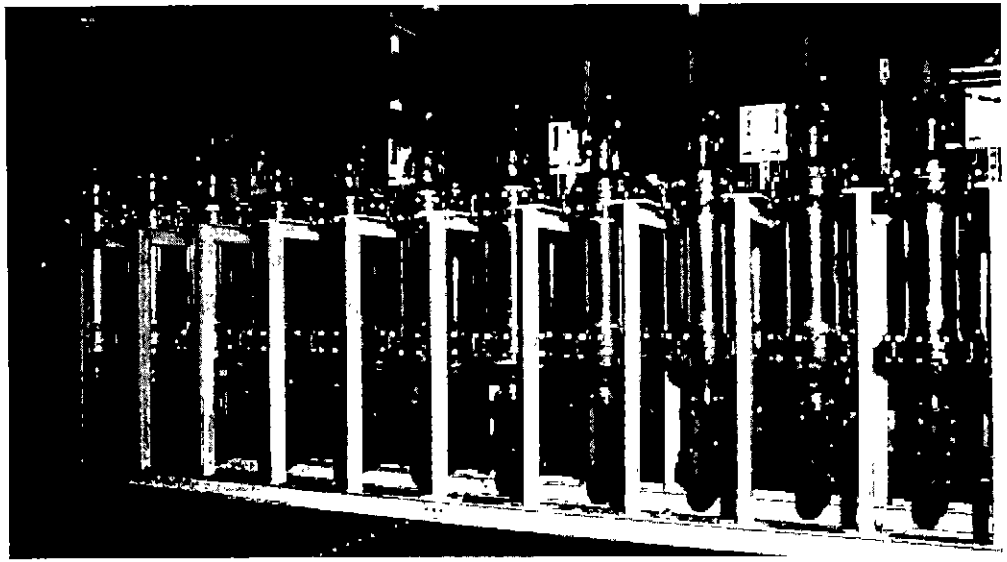
< 20 ppb Dissolved O_2

Gas-Transfer-Solutions

Central UPW Deoxygenation System, Vertically Mounted

Liqui-Cel®

Membrane Contactor



Gas-Transfer Co...

Design Basis:

2500 gpm (570 m^3/hr)

80°F (27°C)

Inlet O_2 (6 ppm)

Outlet Achieved:

< 200 ppb Dissolved O_2

System Design:

Eighteen Trains of Two Contactors in Series Thirty Six 10×8 Contactors

316 L SS Housings 25 RA Finish

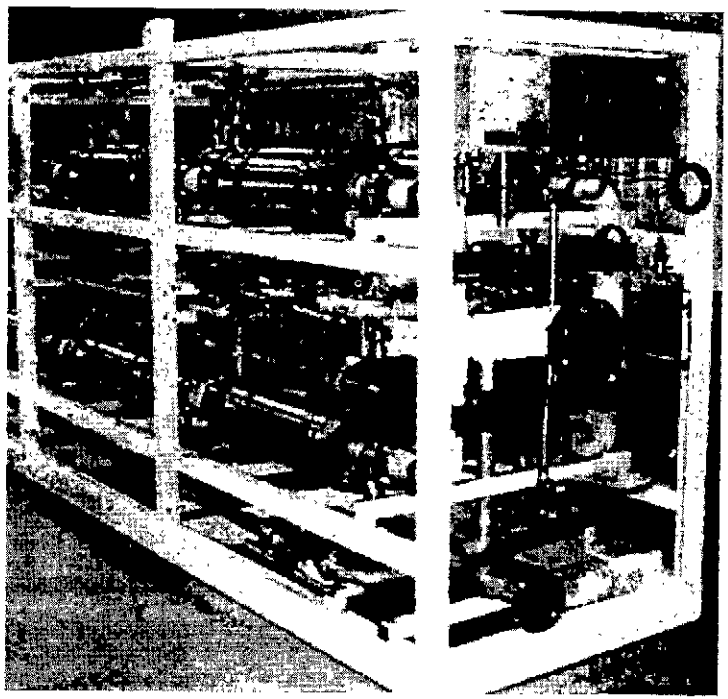
27 in. Hg Vacuum (75 mm Hg Vacuum)

N_2 Sweep – 14.4 scfm (23 m^3/hr)

PG-P56UPW2000 30

Central UPW System, Horizontally Mounted

Liqui-Cel®
Membrane Contactor



Design Basis:

950 gpm	(215 m^3/hr)
75°F	(24°C)
Inlet O_2	Saturated (8.6 ppm)

Outlet Achieved:

< 1 ppb Dissolved O_2

System Design:

Eighteen Trains of Four Contactors in Series. Thirty Two 10×28 Contactors

316 L SS Housings 35 RA Mechanical Finish

28.3 in. Hg Vacuum (40 mm Hg Vacuum)

16 scfm N_2 Sweep

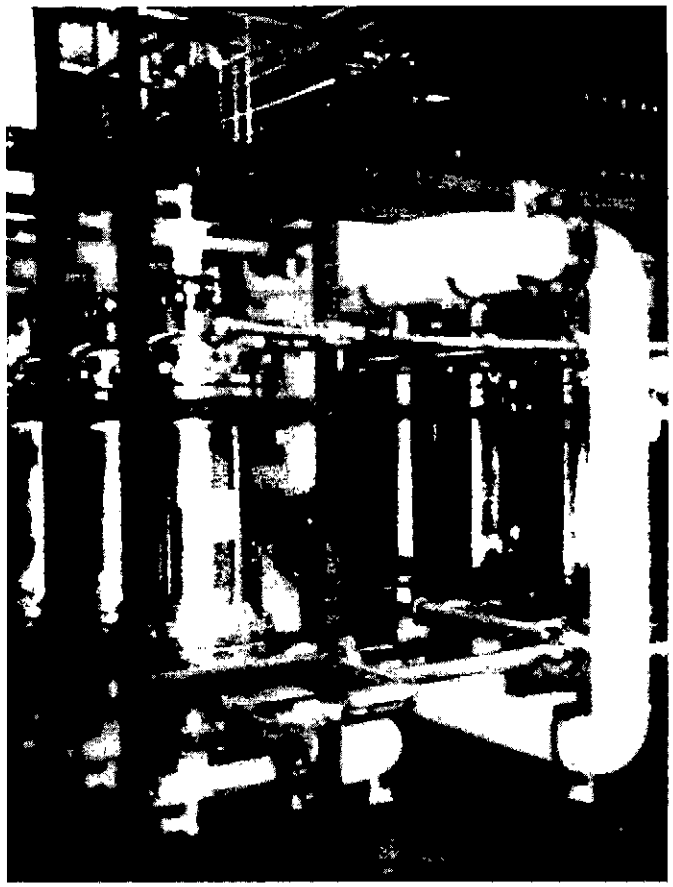
Gas-Transfer Solutions

PC-P56UPW2000 31

Central UPW Deoxygenation System

Liqui-Cel®

Membrane Contactor



Design Basis:

500 gpm (113.5 m^3/hr)

70°F (21°C)

Inlet O_2 (4.5 ppm)

System Design:

Three Trains of Two 10×28 Contactors in Series

Expansion Option of Additional Three Contactors

316 L SS Housings 25 RA Finish

28 in. Hg Vacuum (50 mm Hg Vacuum)

N_2 Sweep – 2.43 scfm (3.90 m^3/hr)

Outlet Achieved:

< 200 ppb Dissolved O_2

Gas-Transfer-Solutions

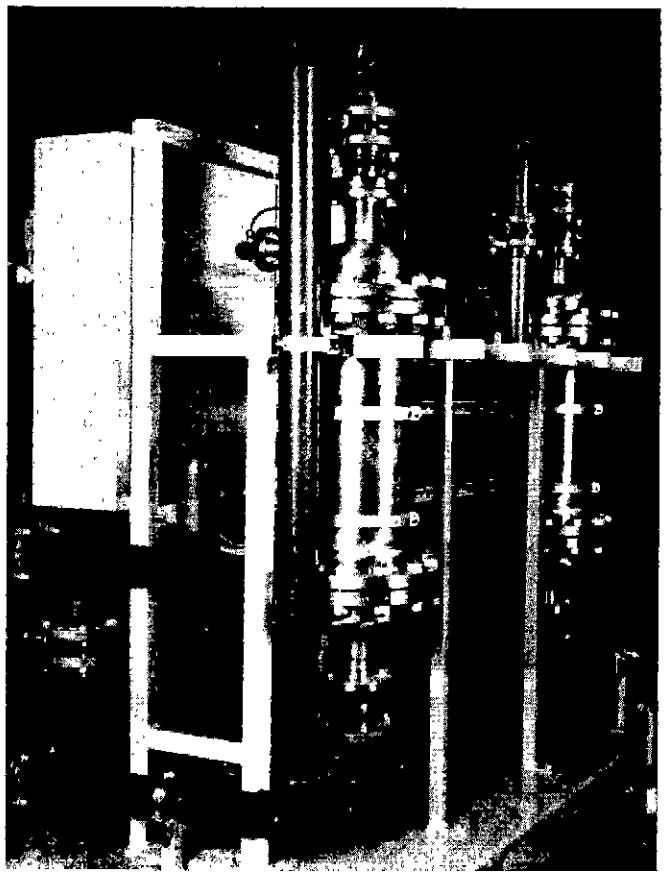
PC-P56UPW2000 32

High Purity Make-Up System at Baltimore Gas & Electric

Liqui-Cel®

Membrane Contactor

Calvert Cliffs, MD



Design Basis:

100–300 gpm	(23–68 m^3/hr)
80°F	(27°C)
Inlet O_2	(6 ppm)
pH	5.60

System Design:

Two in Parallel Feeding One in Series or Three in Parallel - 10×28 Contactors

316 L SS Housings with 35 Ra Mechanical Finish

28 in. Hg Vacuum (50 mm Hg Vacuum)

Outlet Achieved:

< 100 ppb Dissolved O_2

< 100 ppb TOC

Also CO_2 Reduction to Enhance Downstream Ion Exchange Capacity

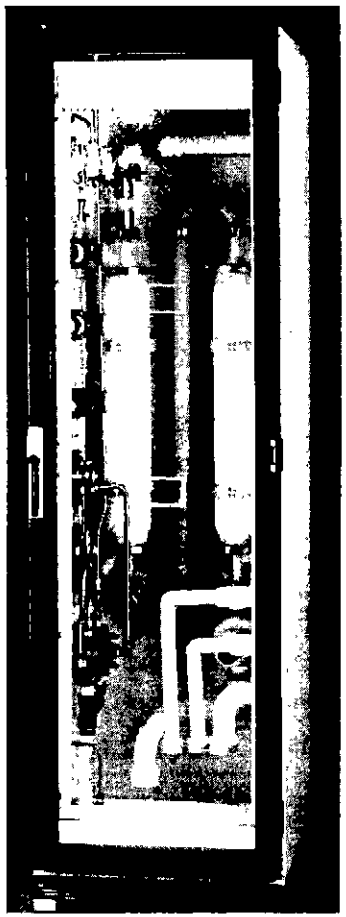
Gas-Transfer-Solutions

PC-P56UPW2000 33

Wet Bench Deoxygenation System

Liqui-Cel®

Membrane Contactor



Design Basis:

10 gpm (2.30 m^3/hr)

77°F (25°C)

Inlet O_2 Saturated (8.5 ppm)

System Design:

Two 4×28 Contactors in Series

Polypropylene Housings, Sanitary Connections

N_2 Sweep – 0.2 scfm (0.3 m^3/hr)

26 in. Hg Vacuum (100 mm Hg Vacuum)

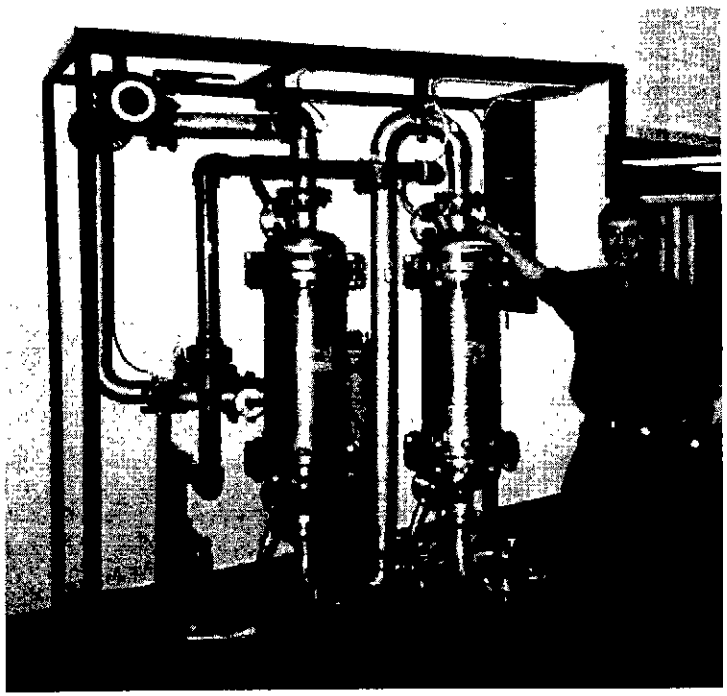
Outlet Achieved:

< 25 ppb

Gas-Transfer-S...

Simultaneous Deoxygenation and Carbonation System

Liqui-Cel® Membrane Contactor



Design Basis:

75 gpm (17 m^3/hr)

35 – 68°F (2 – 20°C)

Inlet O_2 Saturated (9.3–13.8 ppm)

System Design:

Two 10×28 Contactors in Series

304L SS Housing

CO_2 Sweep

Outlet Achieved:

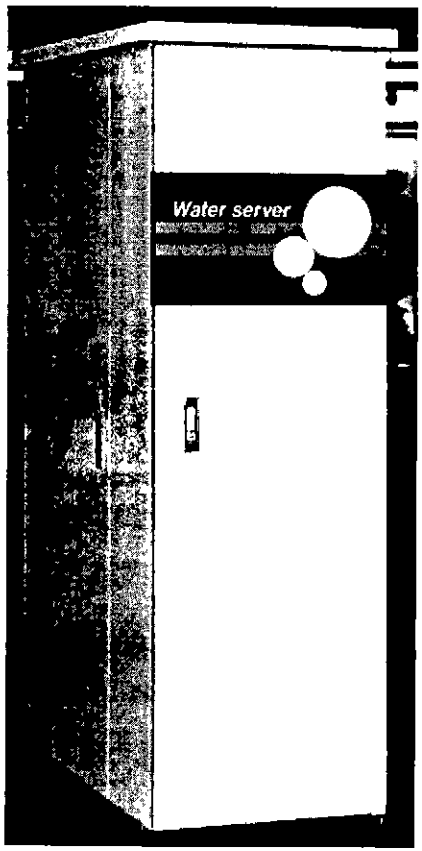
< 100 ppb Dissolved O_2

Carbonated Water

Gas-Transfer-Solutions

Building Water Deoxygenation System

Liqui-Cel® Membrane Contactor



Design Basis:

25 – 50 gpm (5.7 – 11.4 m^3/hr)

77°F (25°C)

Inlet O_2 Saturated (8.5 ppm)

System Design:

One or Two Parallel Trains of
Two 4×28 Contactors in Series

28 in. Hg Vacuum (50 mm Hg Vacuum)

Outlet Achieved:

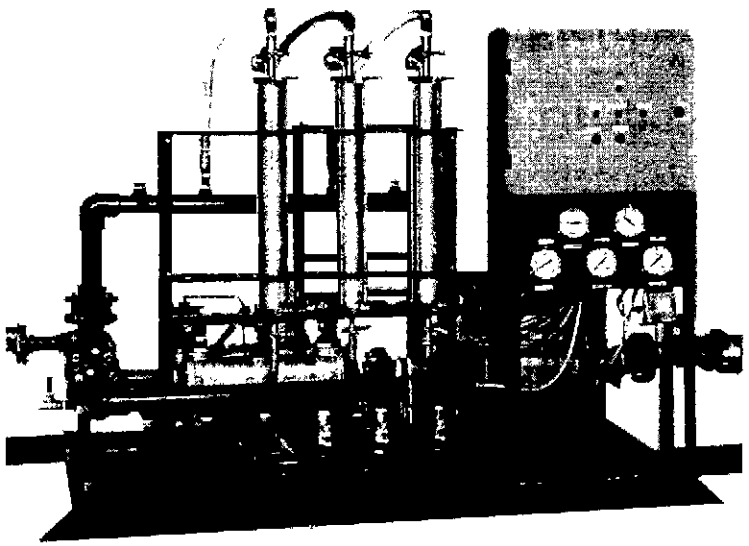
< 500 ppb Dissolved O_2

Gas-Transfer-Solutions

Boiler Deoxygenation System

Liqui-Cel®

Membrane Contactor



Design Basis:

25 gpm (5.7 m^3/hr)

77°F (25°C)

Inlet O_2 Saturated (8.5 ppm)

System Design:

Three 4×28 Contactors in Parallel

316L SS Housing

28 in. Hg Vacuum (50 mm Hg Vacuum)

Outlet Achieved:

< 500 ppb Dissolved O_2

Gas-Transfer-Solutions

Benefits Summary

Liqui-Cel® Membrane Contactor

- Small, Compact
- Modular Like other Water System Components
- Reliable and Predictable
- Responsive to Changes in Flow Rates
- Low Pressure Drop
- Proven in the Field with > 5 Years of Installations
- Warranty to < 1 ppb for O_2 and < 1 ppm for CO_2

Gas-Transfer-Sol...