



Specializing in Air/Gas & Water Processes

Since 1980



The First Year of Maintenance is FREE

TCR - Series TOTAL CONTAMINANT REMOVAL SYSTEMS

Landfill, Digester & Bio Gas

Siloxanes Removed to PPB Level

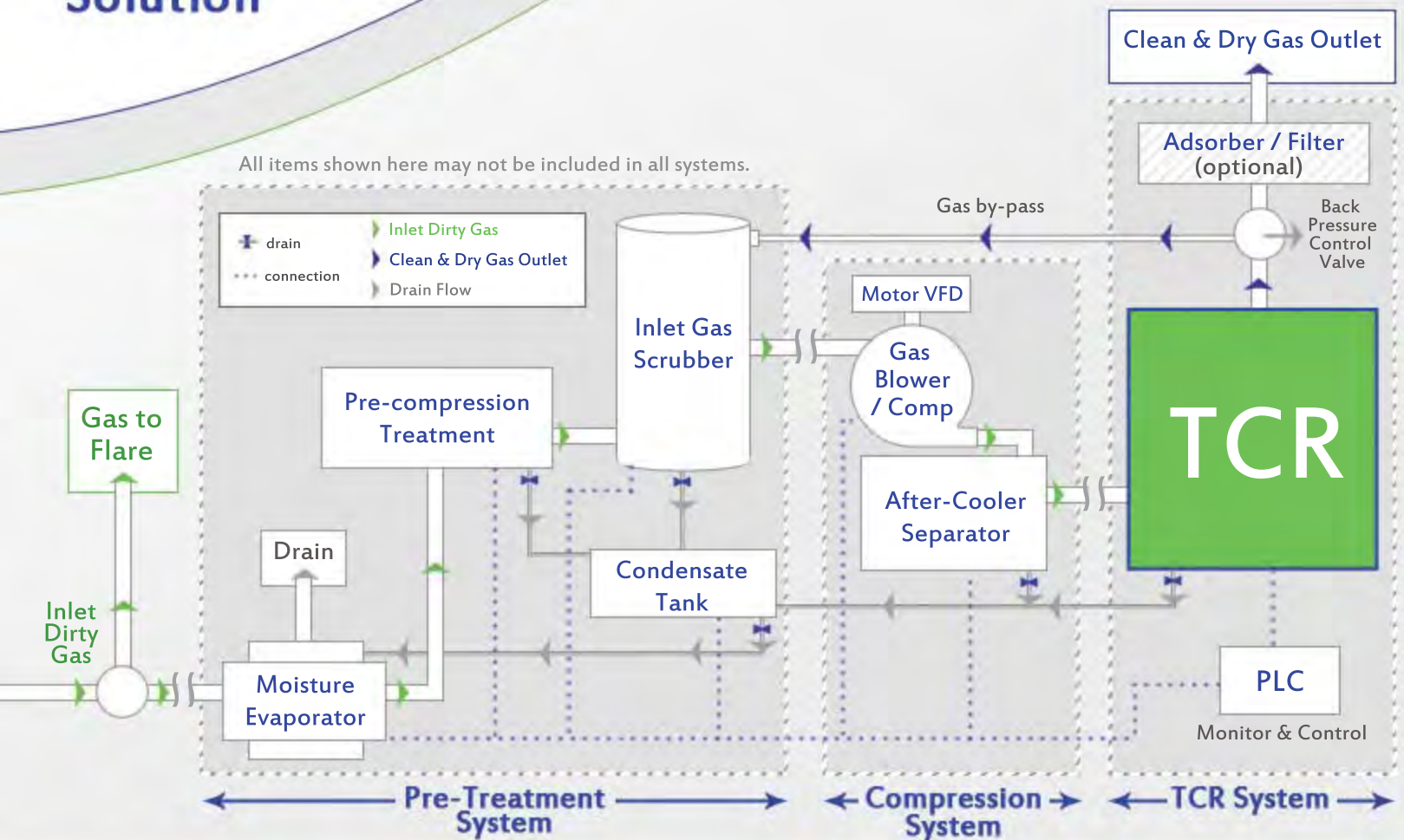
Patent # 6,712,885

A Sustainable
Solution

Factory Integrated Systems

Include - Pre-Treatment + Gas Compression + TCR

All items shown here may not be included in all systems.



COMMONLY ASKED QUESTIONS & ANSWERS:

1. Who shall test the Gas?

Accurate biogas analysis is a difficult and challenging task. Therefore, your gas testing should only be done by an independent and accredited laboratory.

2. How often should the Gas be tested?

Biogas composition from a landfill or wastewater treatment plant (digester gas) can change quickly. Therefore, the testing should be repeated once every six months.

3. What should the Gas be tested for?

At the minimum, the gas should be tested for – Methane, Oxygen, Nitrogen, Carbon Monoxide, Carbon Dioxide, Hydrogen, Oxygen, Siloxanes & Sulfides (H_2S & SO_2).

4. What's the key energy Gas component?

Methane

5. What are the most harmful components in Gas?

Moisture, Siloxanes & Sulfides (H_2S & SO_2)

6. Are there other harmful Gas components?

Yes, Chlorides & Fluorides.

7. Why should Siloxanes be removed?

Because, Siloxanes damage Internal Combustion (IC) Engines, Micro turbines, Boilers and SCR. When heated, Siloxanes form sand like white powder, which can coat components and cause seizure of moving components.

8. Why should we remove Sulfides?

When mixed with moisture, Sulfides form acid which corrodes the surfaces it comes in contact with.

9. How to remove harmful gas components?

A combination of the following processes is the most effective way to clean gas -

- A. Filtration / Separation
- B. Chilling gas - Condenses contaminants for easier separation.
- C. Adsorption - Use of Activated Carbon / Graphite or Adsorption material e.g. Molecular Sieves

10. Is a Gas Blower / Compressor required?

Yes, A blower or compressor provides gas pressure to move gas thru cleaning equipment, piping, valves etc. and provide sufficient gas pressure to the device(s) requiring the gas.

11. How much Gas pressure is required?

Determine the gas pressure required by the device (s) using the gas: add to it the pressure losses thru cleaning equipment, piping, valves etc.

12. Which one is required, blower or compressor?

A typical blower can provide up to 15 PSIG gas pressure, which is usually sufficient for most low pressure devices e.g. Boilers & IC Engines. A gas compressor is usually required for devices requiring a higher gas pressure e.g. Micro-turbines & Turbines.

CASE STUDY

The Quadrogen and Pioneer Air team has recently delivered a biogas clean-up system operating on anaerobic digestion gas at the Orange County Sanitation District Wastewater Treatment Plant in California. This gas is being cleaned for a DFC300, which is producing renewable power, heat, and hydrogen. Initial testing from the Quadrogen Gas Clean-up System has shown that all sulfur species and all halogen species at the outlet of the Quadrogen clean-up skid are below the minimum detection limit of 25 ppbv.

REMOVING SULFUR, SILOXANES, VOC, AMMONIA AND MOISTURE

Bio-gases contain a large amount of pollutants. If released to atmosphere, the pollutants damage atmosphere. When gas is used to produce energy, most harmful pollutants are destroyed; it turns a liability into an asset.

PIONEER HAS THE SOLUTION!!!

We have developed a patented Gas Cleaning process which removes these contaminants by **filtration, cooling, water spray/wash & adsorption**. This Process removes Sulfur, Siloxanes, VOC, Ammonia and Moisture.



SILOXANES

When heated, Siloxanes form sand like white powder, which can coat components and cause seizure of moving components.

PROBLEMS

Consumer and industrial products i.e. toiletries, cosmetics, lubricants & sealants, use silicone as a dispersing agent. Through waste disposal, silicone compounds, or "Siloxanes" are introduced into sewage and landfills. As gas is recovered, Siloxanes, Sulfur, Ammonia & VOC flow with it. As gas is used, siloxanes break down into white abrasive powder, which damages equipment. Some contaminants, e.g. H_2S mix with condensed moisture to form acid, which corrodes surfaces coming in contact with it. For reliability of power generation these contaminants should be removed.

GAS CLEANING SOLUTIONS

FILTRATION: Separates particulates & condensed fluids

Advantages: A simple & inexpensive process

COOLING: Condenses vapors, which dissolve some contaminants; most siloxanes condense at $-9^{\circ}F$ ($-23^{\circ}C$).

Advantages: Minimal waste, less maintenance - lower operating cost

WATER SPRAY/WASH: Dissolves & removes H_2S & VOC

Advantages: A simple & inexpensive process

ADSORPTION: Removes contaminants smaller than its pores sizes e.g. H_2S , VOC and Siloxanes

Advantages:

1. Simple process
2. Lower capital cost
3. Removes a broad range of contaminants

Disadvantages:

1. High media procurement & disposal costs
2. Liability- Creates potentially hazardous waste
3. High maintenance
4. Causes down time during media change

HELPFUL DATA

1 SCFM = $1.56 \text{ NM}^3/\text{H}$ = 1.7 SCMH

1 Cu. Ft. Nat. Gas = 1000BTU

1 US Gallon of water = 8.34 lb

1 PSI = 0.069 BAR = 2.31 ft =

2.036" Hg = 2.13' H_2O = 6.9 KPa

1 Cu. Ft. = 7.5 US Gallons

1 KWH = 3415 BTU

1 HP = 0.76 KW

1 Kg = 2.2 lb

1 Kilo Calories = 4 BTU

SCFM - Standard ft^3/min
($68^{\circ}F/14.7 \text{ PSIA}$)

NM^3/H - Normal m^3/hour ($0^{\circ}C$ & 1 BAR)

Air Density ~ $0.075 \text{ lb}/\text{ft}^3$ or $1.2 \text{ kg}/\text{m}^3$

Specific heat (C_p) ~ $0.24 \text{ Btu} / \text{lb} / ^{\circ}F$ or
 $1 \text{ KJ} / \text{kg} / ^{\circ}K$

Methane Density ~ $0.042 \text{ lb}/\text{ft}^3$ or
 $0.67 \text{ kg} / \text{m}^3$

Specific heat (C_p) ~ $0.59 \text{ Btu} / \text{lb} / ^{\circ}F$ or
 $2.22 \text{ KJ} / \text{kg} / ^{\circ}K$

CNG, Biogas density & specific heat are similar to that of methane

Table 1

Typical Performance & Comparison

Table 2

Contaminant	RD-Series Removal	Process	TCR Removal	Process
Moisture (% / PDP)	> 80% (+40°F)	Condensation	>98% / -10°F / -23°C	Condensation
Particulates (Dust)	> 99%	Filtration	> 99.9%	Filtration
Heavy Hydrocarbons	5% - 10%	Condensation	10% - 20%	Condensation
Ammonia	Solubility: 89g/100cc	Dissolves	Solubility: 89g/100cc	Dissolves
Hydrogen Sulfide	Solubility: 437g/ liter	Dissolves	Solubility: 437g/ liter	Dissolves
Halides/Chlorine/Fluorine	Solubility (varies)	Dissolves	Solubility (varies)	Dissolves
Siloxanes	Approx. 40% - 50%, w/o carbon/desiccant	Condensation	Approx. 90% - 98%, w/o carbon/desiccant	Condensation & controlled freezing

DESIGN CONDITIONS

Gas Dew Point: -23°C / -10°F
 Inlet temp: 120°F / 49°C (maximum)
 Amb temp: 110°F / 43.3°C (maximum)

INSTRUMENTS / CONTROLS

Class 1, Group D & Division 1/2
 Control Panel: NEMA 4X
 Single Point Power Feed
 Electro Mechanical / PLC Controls
 Motor controls
 Fusible Disconnect / Circuit Breaker
 Refrig. Suction Pressure Reading
 Refrig. Disch. Pressure Reading
 Dew Point Temperature Reading
 Gas Inlet Temperature Reading
 Gas Outlet Temperature Reading
 Gas Inlet Pressure Reading
 Gas Outlet Pressure Reading
 Filter (s) Pressure Drop Reading

Alarms:

- High DP across filter(s) -
- High Liquid Level - Separators
- High Liquid Level - Filters
- High Refrigerant Pressure
- Low Refrigerant Pressure
- Low Inlet Gas Pressure
- Low Outlet Gas Pressure



Removes 99.9% Contaminants with Carbon Adsorbers*

DESCRIPTION

A TCR includes "A unique set of Gas to Refrigerant Heat Exchangers".

Most **SILOXANES*** condense at -9°F (-23°C). To cool gas below freezing temperature, without blocking gas flow due to ice build up, gas flow alternates between two heat exchangers. One heat exchanger chills gas to -9°F; while the other is de-frosted; and, chilled again before the gas flow switches, to provide a low dew point continuously.

To prevent freeze up, gas temperature and pressure are monitored at critical points; gas flow, pressure & temperature are controlled by a PLC. Similarly, the cold and warm refrigerant flows pressure & temperature are monitored and controlled by a PLC.

Gas is cooled in multiple steps. Most contaminants either condense, or dissolve, in moisture / fluids.

ADVANTAGES

1. Lower Capital Cost
2. Lower Piping Cost
3. Lower Wiring Cost
4. Lower Programing Cost
5. Single Source Responsibility
6. Better Component Compatibility

Energy Efficient - Condensate recovery & moisture evaporation reduce energy requierment for the treatment system.

Total Contaminant Removal Selection Guide

MODEL #	KW +/- 10%	* BLOWER HP	SCFM @ 100 PSIG	* SCFM @ 7 PSIG	Carbon Adsorber	In / Out Inch FLG	APPROX WEIGHT (LB)	APPROX DIM (inch) L x H x W
TCR5T	5	7.5	300	100	200 lb	2"	3000 lb	72 x 48 x 96
TCR8T	8	10	480	160	300 lb	3"	5000 lb	96 x 72 x 96
TCR10T	10	15	600	200	400 lb	3"	8000 lb	120 x 90 x 96
TCR15T	15	20	900	300	600 lb	4"	11000 lb	150 x 90 x 96
TCR20T	20	25	1200	400	800 lb	6"	14000 lb	210 x 90 x 102
TCR25T	25	30	1500	500	1000 lb	6"	17000 lb	240 x 90 x 102
TCR30T	30	40	1800	600	1200 lb	6"	20000 lb	270 x 90 x 102
TCR35T	35	40	2100	700	1400 lb	8"	24000 lb	300 x 90 x 108
TCR40T	40	50	2400	800	1600 lb	8"	27000 lb	330 x 90 x 108
TCR45T	45	60	2700	900	1800 lb	10"	31000 lb	360 x 90 x 120
TCR50T	50	60	3000	1000	2000 lb	10"	34000 lb	390 x 90 x 120
TCR55T	55	75	3000	1100	2200 lb	10"	37000 lb	420 x 90 x 120
TCR60T	60	75	3600	1200	2400 lb	10"	40000 lb	450 x 90 x 120

* For low pressure applications <10 PSIG

Table 3

ADVANTAGES

1. Removes 98% contaminants without Carbon Adsorbers / up to 99.9% with Carbon Adsorbers.
2. Eliminates adsorber media replacement, handling, down time and material costs in most applications.
3. Risk of disposing a potentially hazardous media is eliminated.
4. Risk of not knowing when to change media is eliminated.



Patent #6,712,885

TCR Flow Diagram

The left heat exchanger cools the gas to -9°F (-23°C) while the right heat exchanger is de-frosted; and, gas flow is reversed after a certain time.

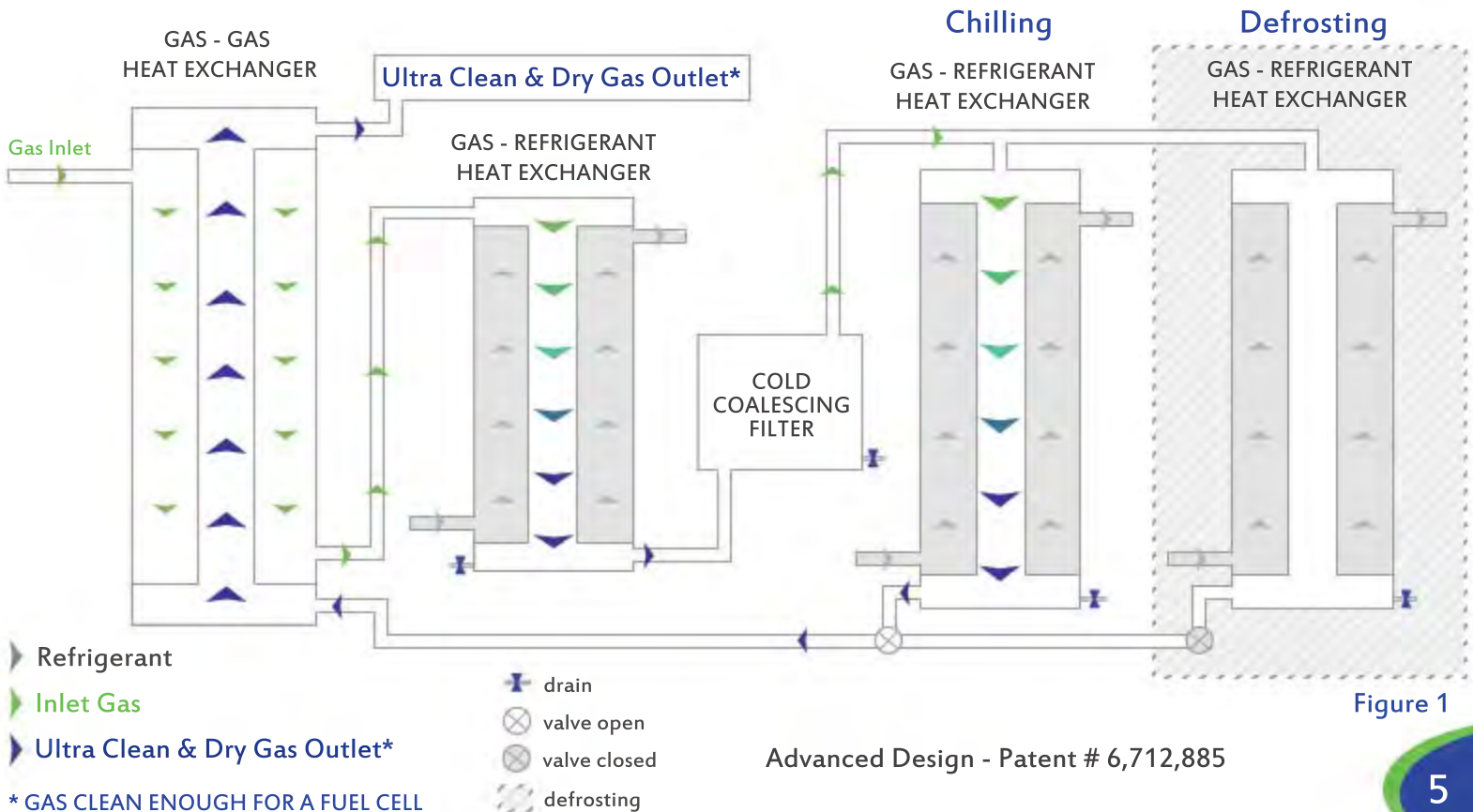


Figure 1

Advanced Design - Patent # 6,712,885

ACTIVATED CARBON / GRAPHITE ADSORBERS



A six vessel Catalytic carbon Adsorber

A typical PIONEER Activated (Catalytic) Carbon Adsorber system uses two (2) vessels, however, more vessels can be provided if required.

In addition to 316L SS screens at gas inlet and gas outlet, each vessel has a dedicated particulate final filter to prevent carryover of media fines; and, inlet & outlet valves for ease of service. In a typical installation, any of the vessels can be serviced without interrupting the gas flow.

The vessels, connecting piping, fittings and accessories are made of CS or 304L SS or 316L SS as required. The carbon steel vessels are coated for rust prevention.

Systems are very effective in removing H₂S, SO₂, VOC, SILOXANES and other contaminants. While the activated carbon is the most commonly used media for cleaning gas, for more demanding applications a blend of Molecular Sieves/ Silica Gel in combination with Activated carbon are available for removing siloxanes and other contaminants.

Gas Flow Options

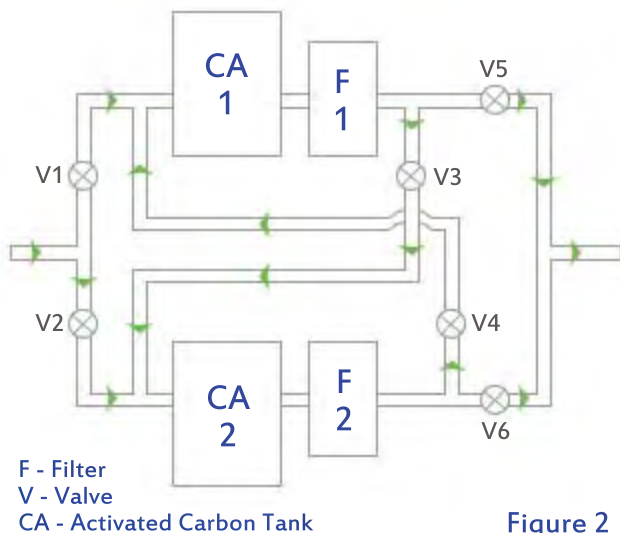


Figure 2

Option 1

In Parallel, 50% thru "CA1 + F1" & 50% thru "CA2 + F2" (close valves V3 & V4, open valves V1, V2, V5 & V6)

ADVANTAGE: Lower Pressure Drop

Option 2

In Series, 100% gas flow first thru "CA1 + F1" and then thru "CA2 + F2" (use fresher media in "CA2 + F2"; close valves V2, V4 & V5; open valves V1, V3 & V6)

ADVANTAGE: Cleaner Gas

Option 3

In Series, 100% gas flow first thru "CA2 + F2" and then thru "CA1 + F1" (For maximum contaminant removal, use fresher media in "CA1 + F1"; close valves V1, V3 & V6; open valves V2, V4, V5)

ADVANTAGE: Cleaner Gas

EXAMPLE

Size an adsorber to lower H₂S levels in 100 SCFM of biogas, density 0.045 lb/CF, from 150 PPM to 50 PPM (V), or by 100 PPM for 180 days.

$$\text{The amount of H}_2\text{S to be removed in 180 days} = \text{SCFM} \times (\text{Minutes} \times \text{Hours} \times \text{Days}) \times \text{Density} \times (\text{H}_2\text{S in ppm}) =$$

SCFM	Minute	Hours	Days	Density	H ₂ S	Removal
100	x	(60 x 24 x 180)	x	0.045	x	(100/1MM) = 116.64 lb

Based on 20 % adsorption rate, activated carbon required = 116.64/ 0.2 = 583.2 lb

Recommend:

C600 with two ASME certified, CS, vessels, coated for rust prevention, each with 300 lb's of catalytic carbon, SS inlet/outlet screens, inlet/outlet filters, inlet/outlet valves for either/or operation, piped and mounted on a single skid.

NOTE: Condensate removal provides additional H₂S removal

SELECTING / SIZING AN ADSORBER

MODEL #	MAX SCFM @ 5 PSIG	VESSEL QTY	APPROX VESSEL SIZE D" x H"	ACTIVATED CARBON (LB)
CA200	100	2	12" x 64"	200
CA300	150	2	12" x 90"	300
CA400	200	2	18" x 64"	400
CA600	300	2	18" x 92"	600
CA800	400	2	24" x 68"	800
CA1000	500	2	24" x 82"	1000
CA1200	600	2	24" x 92"	1200
CA1400	700	2	30" x 78"	1400
CA1600	800	2	30" x 84"	1600
CA1800	900	2	30" x 90"	1800
CA2000	1000	2	36" x 72"	2000
CA2200	1100	2	36" x 78"	2200
CA2500	1250	2	36" x 90"	2500
CA3000	1500	2	36" x 96"	3000
CA4000	2000	2	42" x 96"	4000
CA5000	2500	2	48" x 96"	5000
CA6000	3000	2	60" x 78"	6000
CA7000	3500	2	60" x 87"	7000
CA8000	4000	2	60" x 96"	8000

Table 4

CATALYTIC CARBON

PIONEER adsorption media is specially designed for removing H₂S. Its catalyst oxidizes H₂S into water soluble sulfur compounds. In addition, catalytic carbon provides an effective removal of VOC compounds.

The carbon life can be extended by washing it with steam.

SPECIFICATIONS

4 x 6 US Sieve; Density: 0.45 kg/liter or 28 lb/CF

H₂S adsorption capacity: 20% by weight (average), varies from 10% to 50%

NOTE:

For more demanding applications a blend of Activated Carbon and Molecular Sieve is provided.

AN ECONOMICAL ALTERNATIVE

H₂S WASH / Pre-Filter (s)

OBJECTIVE:

Reduce H₂S level from 150 to 50 or by 100 PPM

Gas flow: 100 SCFM

Amount of H₂S to be removed in 1 hour =
 SCFM (Minutes) H₂S (D) H₂S PPM
 100 x 60 x 0.045 x 100/1MM = 0.027 lb/ hr

Adsorption rate ~ 0.4 g/100 mL (20 °C) or 4 g/ liter
 0.027 lb/hr = 0.027 x 453.6 = 12.2 grams / hour

Amount of water required to dissolve 12.2 grams/hr of
 H₂S = (12.2/4) = 3.06 Liter /hr = 0.81 GPH



A factory integrated, 400 SCFM, gas processing system with Adsorbers and Gas Screw Compressors.

BLOWER & COMPRESSOR PACKAGES

Blowers & compressors are specially designed for biogas; built with materials compatible with the acidic gas; and, sized for required gas flow as well as gas pressure.

Systems include a generously sized low micron inlet filter (0.9micron) to protect blowers/compressors and a re-circulation valve to provides gas flow & pressure control at the gas outlet.

For critical applications, in addition to post-compression treatment PIONEER offers pre-compression treatment to protect blower/compressor.

Standard Quality Features:

- Factory integrated with balance of the gas processing system
- 316L SS, 0.9 Micron, Inlet Filter-Scrubber, automatic drain valve, test drain valve and High liquid level alarm
- Gas outlet flow control
- Gas outlet pressure control
- Back pressure regulating valve
- 304L or 316L SS After cooler
- 304L or 316L SS Moisture Separator & drain
- TEFC motor(s)
- Motor Controls & Overload protection
- VFD/ VSD - Regulates blower speed; i.e. Gas flow/ pressure - saves energy

Gas Compression: Up to 350 PSIG



A PIONEER Model R150A-PP complete with COPELAND/EMERSON Scroll Gas Compressor with Pre & Post Gas Cleaning

Standard Safety Features:

- High pressure shut down & alarm
- High temperature shut down & alarm
- Pressure relief valve

SELECTING / SIZING

Table 5

MODEL #	HORSE POWER	INLET PRESSURE	FLOW @ DISCHARGE	PRESURE @ DISCHARGE
PGB5	5	4"-10" wc	100 SCFM	@ 5 PSIG
PGB7	7.5	4"-10" wc	150 SCFM	@ 6 PSIG
PGB10	10	4"-10" wc	200 SCFM	@ 7 PSIG
PGB15	15	4"-10" wc	300 SCFM	@ 7 PSIG
PGB20	20	4"-10" wc	400 SCFM	@ 7 PSIG
PGB25	25	4"-10" wc	450 SCFM	@ 8 PSIG
PGB30	30	4"-10" wc	550 SCFM	@ 8 PSIG
PGB40	40	4"-10" wc	700 SCFM	@ 8 PSIG
PGB50	50	4"-10" wc	800 SCFM	@ 8 PSIG
PGB60	60	4"-10" wc	1000 SCFM	@ 8 PSIG
PGB75	75	4"-10" wc	1200 SCFM	@ 8 PSIG
PGB100	100	4"-10" wc	1500 SCFM	@ 8 PSIG

EXAMPLE:

Required - 500 SCFM (maximum) of gas at 2 PSIG at inlet to a Gen-set

Pressure loss in piping, fittings & valves: 1 PSIG
 Pressure drop thru gas treatment system: 3 PSIG
 Margin of safety: 1 PSIG

Required blower pressure = (2+1+3+1) = 7 PSIG

Required blower capacity: 500 SCFM @ 7 PSIG

RECOMMEND: PIONEER Model PGB30

OPTIONS:

1. Explosion proof motor
2. 316L SS or 304L SS
3. Back-up Gas Blower/Compressor with isolation and pressure relief Valves
4. Fusible Disconnect or Circuit Breaker
5. Stand alone skid
6. Outdoor enclosure
7. Pre-Compression Treatment

Most gas blowers are limited to a pressure of 15 PSIG at blower outlet. For up to 15 PSIG blower discharge pressure PIONEER offers -

- AMETEK/ ROTRON - Regenerative Blowers
- GARDNER DENVER - Positive Displacement Blowers

Higher gas pressures are required for Micro-turbines, Turbines & Gas Transmission. For it PIONEER offers -

- EMERSON SCROLL - Gas Compressors
- GARDNER DENVER - Screw Gas Compressors

Ten Year Limited Warranty

Longest Warranty in Industry



PIONEER systems are warranted to be free from defects in material and workmanship for a period of one year from the date of installation, or up to 24 months from the date of shipment, whichever comes first, provided the equipment is installed and used according to the company's recommendation.

The company's liability is limited to the repair, refund, or replacement in kind at the company's sole option. In no event will the company be liable or responsible for incidental and consequential damages, even if the possibility of such has been made known to the company. Normal maintenance items are excluded. Key components, heat exchangers & refrigerant compressors carry a ten-year pro-rated warranty.



"Non-Standard Equipment is our Specialty" *Since 1980*

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WATER COOLING SYSTEMS • SEPARATORS • A.S.M.E. VESSELS • HEAT EXCHANGERS
NATURAL GAS FILTRATION & DRYING • BIOGAS CLEANING & DRYING

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