## Introduction

Varec Biogas offers a wide range of biogas safety and handling equipment. Biogas is typically produced during the biological breakdown of organic solids through anaerobic digestion. The gas generated through this process is an energy source which can be collected and utilized, or can be safely burned. Biogas is a highly moist mixture of gases consisting of approximately 55 to 70% methane, 25 to 35% carbon dioxide and trace amounts of nitrogen and hydrogen sulfide. Biogas recovered may be used in a multitude of ways. Biogas can be used to run a boiler for heating the anaerobic digester or the plant. Biogas can also be used to run an engine-generator to generate electricity.

Anaerobic digestion is one of the most safe and effective methods of treating biosolids from municipal and industrial wastewater. It is an ideal method in meeting strict environmental regulations in highly urban areas. The anaerobic process occurs in closed vessels (digesters), or covered ponds or lagoons. Soluble organics are converted to methane ($CH_4$) and carbon dioxide ($CO_2$) in a two-step process.

Landfills also generate biogas naturally as buried organic refuse biodegrades.

## Biogas Safety & Handling System

Biogas collection and utilization is an important part of the anaerobic digestion process. The low heat content gas is saturated, and contains elements harmful to personnel. Biogas is also corrosive to piping and equipment.

It is important to handle biogas properly to ensure a protected environment. The key aspect of design is to recognize that biogas handling equipment operates as a system. The following provides general guidelines for the design and selection of a complete biogas safety and handling system.

With over seven decades of experience and service to the industry, Varec Biogas is proud of its high-quality worldwide performance record.

## System Flow Diagrams

### System Flow

Biogas is produced within the digester at a rate that creates enough pressure to move gas through the piping system. In some systems, this gas is first recirculated to the primary digester to assist in mixing the digester contents.

**DIAGRAM 1**
Typical Layout of Digester Outlet

**DIAGRAM 2**
Directed to the Boiler for Digester Heating or Plant Heating

**DIAGRAM 3**
Used as Fuel for GAS Engine with Gas Conditioning/ Drying

**DIAGRAM 4**
Biogas Directed to the Waste Gas Burner Through the Regulator

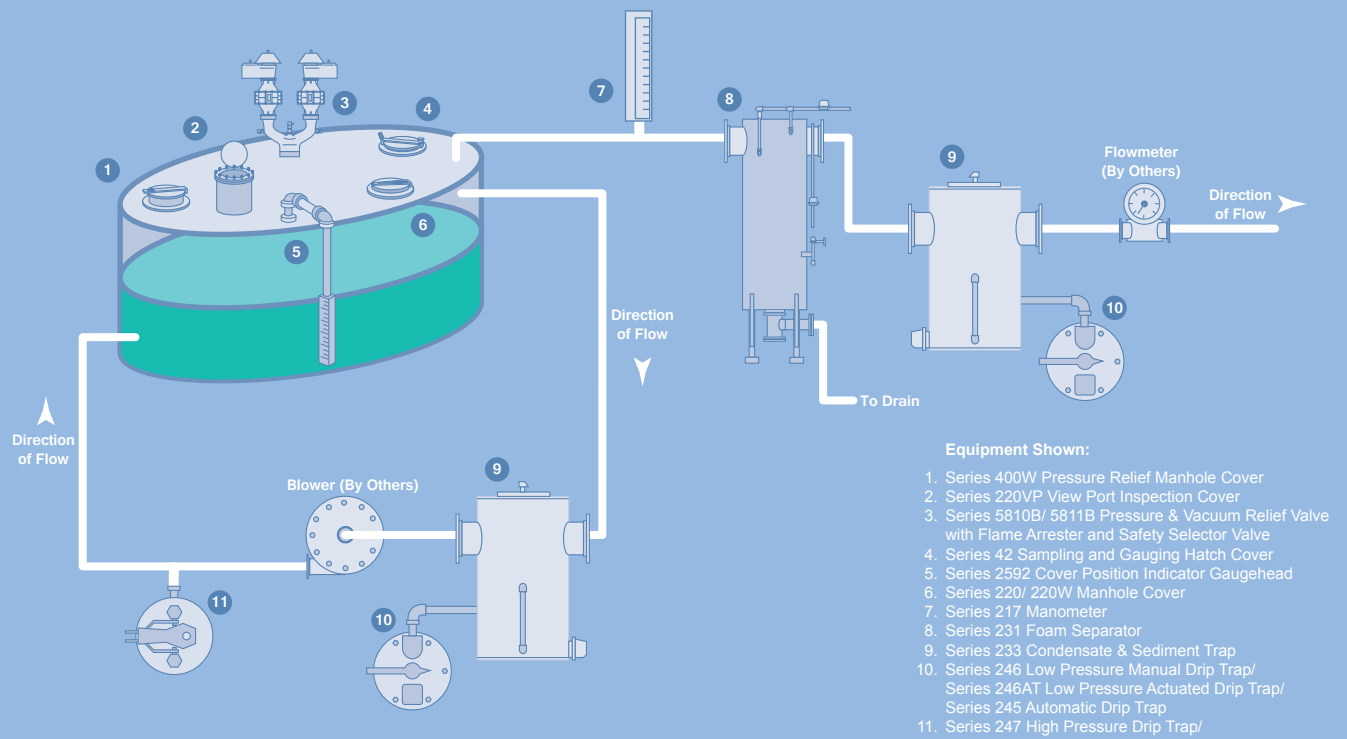
OR

**DIAGRAM 5**
Installation of Biogas Directed to an Enclosed Flare

### DIAGRAM 1: DIGESTER COVER ACCESSORIES / DIGESTER GAS TAKE-OFF LINE

**HINTS**

**1. Many digesters generate foam which can clog equipment, therefore, it is recommended to place a gas/foam separator downstream of your digester.**



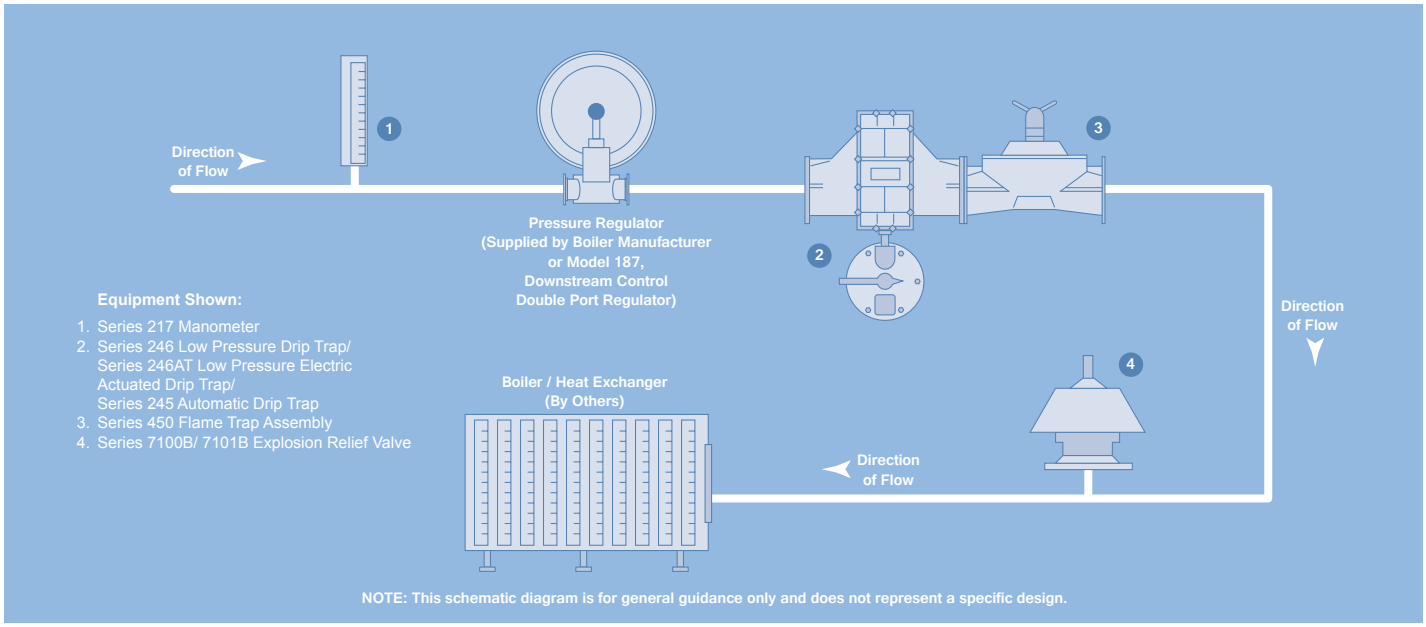

**Equipment Shown:**

1. Series 400W Pressure Relief Manhole Cover
2. Series 220VP View Port Inspection Cover
3. Series 5810B/ 5811B Pressure & Vacuum Relief Valve with Flame Arrester and Safety Selector Valve
4. Series 42 Sampling and Gauging Hatch Cover
5. Series 2592 Cover Position Indicator Gaugehead
6. Series 220/ 220W Manhole Cover
7. Series 217 Manometer
8. Series 231 Foam Separator
9. Series 233 Condensate & Sediment Trap
10. Series 246 Low Pressure Manual Drip Trap/ Series 246AT Low Pressure Actuated Drip Trap/ Series 245 Automatic Drip Trap
11. Series 247 High Pressure Drip Trap/ Series 247AT High Pressure Electric Actuated Drip Trap

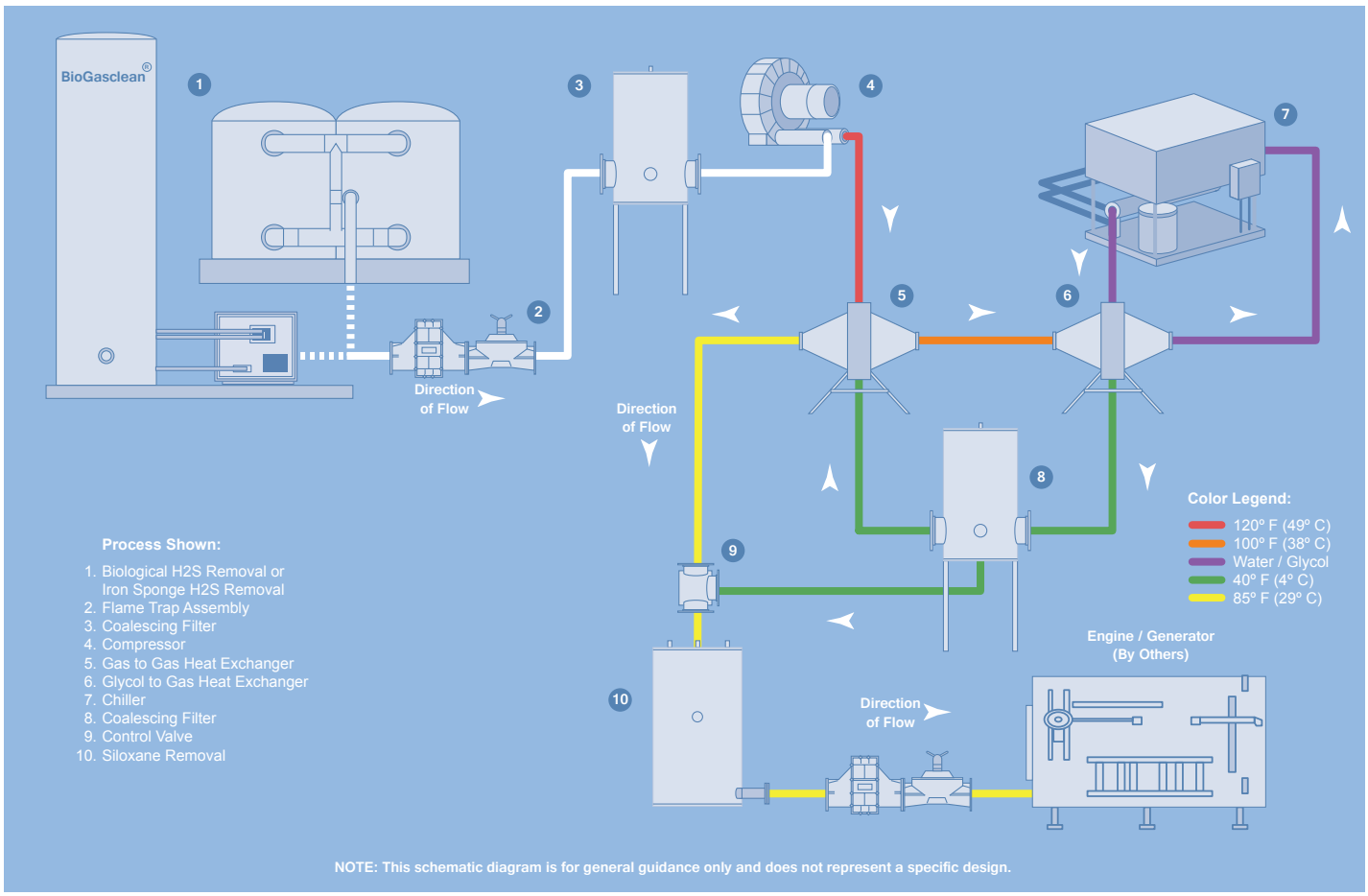
**NOTE: This schematic diagram is for general guidance only and does not represent a specific design.**

## System Flow Diagrams

### DIAGRAM 2: DIGESTER GAS TO BOILER

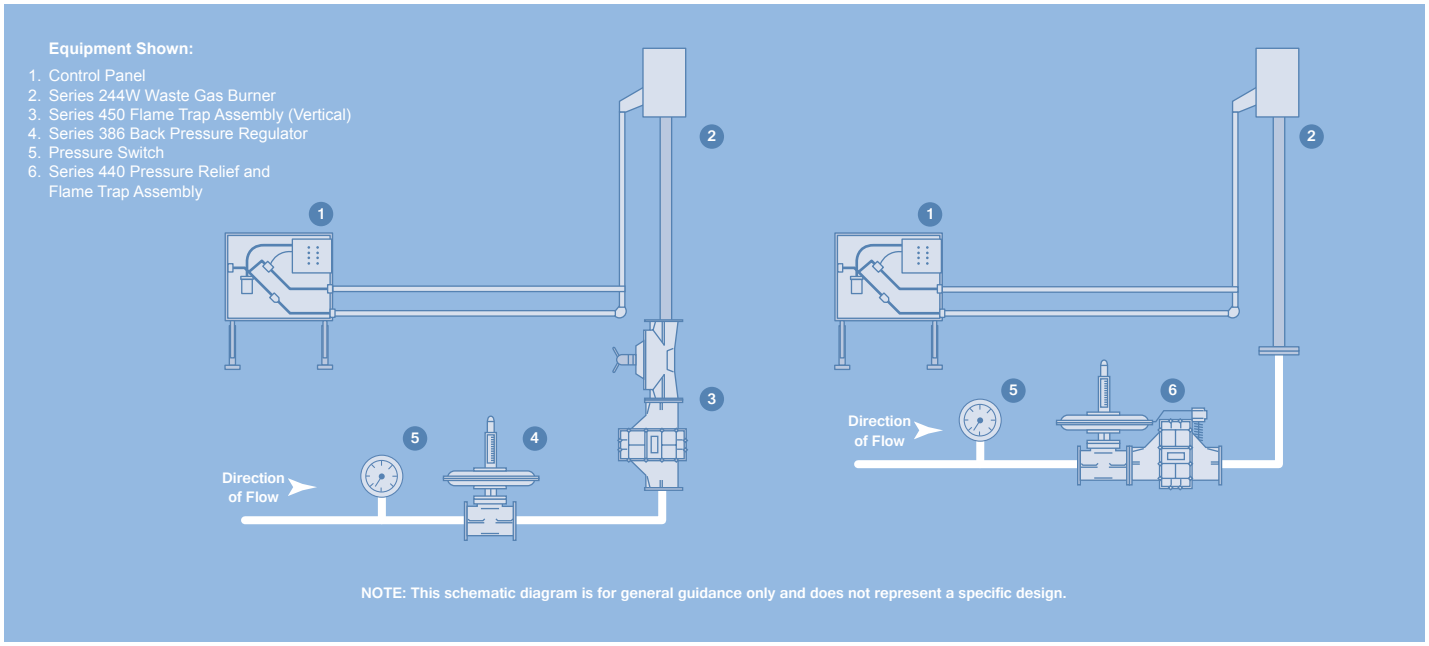



### DIAGRAM 3: DIGESTER GAS TO ENGINE GENERATOR



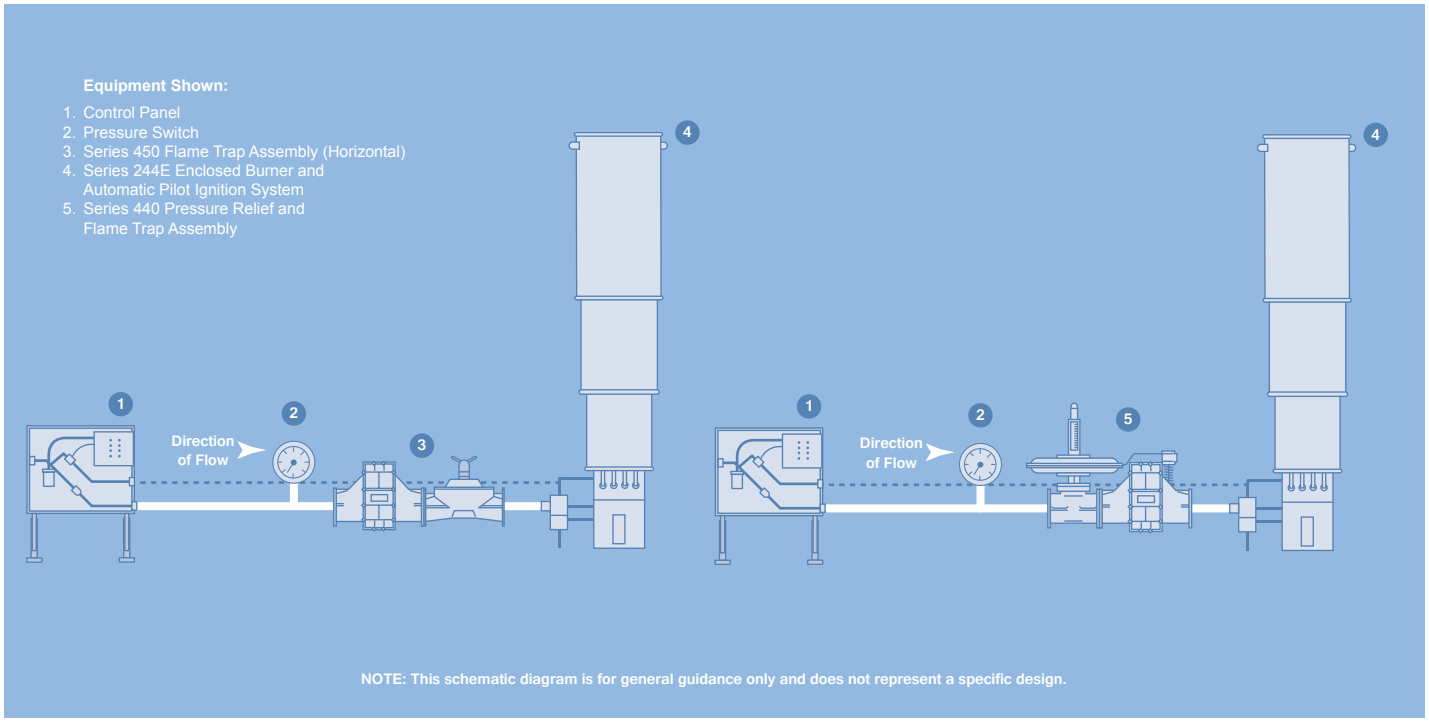
## System Flow Diagrams

### DIAGRAM 4: WASTE GAS BURNER




**OR**

### DIAGRAM 5: ENCLOSED FLARE



## Biogas Systems

SYSTEM HYDRAULICS

When sizing the gas piping and equipment, the following parameters should be considered:

1. Biogas production flow capacity.

2. Pipe diameter, length and fitting - The Water Environment Federation (WEF Manual of Practice No.FD - 8) recommends that piping should be sized with a maximum gas velocity below 12 ft/s (3.7 m/s). This velocity will prevent liquid and solid carry-over which damages equipment. Additionally, the number of pipe bends and long piping runs should be minimized to reduce pressure losses.

3. Maximum digester cover design pressure can be calculated by determining the amount of gas produced by the digester. Gas production may be estimated using various published calculations. Select the pipe size necessary to stay within the recommended velocity requirements. Determine the pressure loss on the gas line leading to the inlet of the gas utilization equipment. The sum of the pressure required at the inlet of the gas utilization equipment and the pressure drop through the line determines the minimum operating pressure necessary beneath the digester cover.

4. Determine required pressure losses through each piece of equipment to maintain low pressure drop across the entire system.

5. The operating pressure necessary for all gas utilization equipment.

6. All gas piping should be sloped a minimum of 2% for proper drainage. Drip traps should be located at all low points, and in long pipe runs.

In more complex systems, it is necessary to determine the minimum inlet pressures and pressure drops for each line before calculating the cover pressure. A gas storage device may be necessary to handle loads during periods of low gas production.

MATERIALS

The gas system must utilize materials which are corrosion resistant to $H_2S$ and to the overall plant environment. Most gas handling equipment is available in low copper cast aluminum, which has proven to be extremely corrosion-resistant in biogas applications.

If fabricated steel is used, a protective coating should be considered. For example, bitumastic coating or coal tar epoxy is extremely corrosion-resistant. Units can also be hot-dipped galvanized by the manufacturer, or field painted with a corrosion-resistant coating system. If units manufactured of carbon steel are not installed immediately, proper storage and handling must be considered.

Stainless steel is the material of choice for corrosion resistance and overall product longevity.

NFPA-820 rated fiberglass can also be used to construct vessels, e.g., $H_2S$ scrubbers.

Heat-resistant materials are important for the waste gas burner. Some units utilize stainless steel in areas of the waste gas burner exposed to elevated temperatures. A protective layer of insulation for carbon steel stacks in enclosed flares is a more cost-effective method than using an all stainless steel chamber.

## Equipment Selection

LIQUIDS AND SOLIDS HANDLING

The biogas is saturated as it leaves the digester, covered pond or lagoon. Moisture and sediment should be removed to avoid damaging downstream equipment. A Condensate and Sediment Trap with drip trap should be located immediately downstream of the digester, or covered pond or lagoon. Refer to 233 and 246 Series for further information.

If large amounts of condensate are expected, installation of a condensate accumulator at the lowest point of the gas piping should be considered to assist in lowering operation and maintenance cost. Refer to 248 Series for further information.

FOAM PROBLEMS

Foaming in the digester may cause operation and safety problems. Foam can clog the gas handling equipment, such as the flame arresters. The following are recommendations to properly handle foaming problems in the digester.

1. Pressure and vacuum relief (PVR) valves with flame arresters are installed on digester covers. In instances when foam clogs the flame arresters, it may prevent the PVR valves from relieving pressure or vacuum build-up in the vessel. Emergency pressure or vacuum relief can be accomplished through the installation of emergency relief manhole covers. Refer to 400W Series for more information.
2. It is important to prevent foam from entering the main biogas train leaving the digesters. An effective method is to install a foam separator immediately downstream of the digester. Refer to 231 Series for more information.

HYDROGEN SULFIDE REMOVAL

Biogas contains varying amounts of hydrogen sulfide ($H_2S$). $H_2S$ is a highly-corrosive substance that can create maintenance and operation problems. To avoid corrosion, the $H_2S$ must be reduced to meet the recommended limit given by the boiler, compressor, or engine manufacturer. $H_2S$ is also a toxic air pollutant that can create a severe odor nuisance even in minute concentrations. The treatment of biogas for removal of sulfur compounds is increasingly important as regulations restricting sulfur emissions become more stringent.

A gas purifier should be installed upstream of boilers, compressors or engine-generators. A flame trap assembly should be installed just upstream and downstream of each purifier. Refer to 235/236 Series.

FLAME PROPAGATION

Flame flashbacks in the biogas piping system have a tendency to propagate. Flame propagation can severely damage equipment.

Flame arresters should be installed 15 feet upstream of all possible ignition sources. Thermal shut-off valves should be used in conjunction with all in-line arresters. They provide added protection by shutting off the gas source to the flame. Refer to 5000, 430 and 450 Series for more information.

Flame arresters should be installed in conjunction with all pressure and vacuum relief valves installed on digester roofs to prevent an external flame from igniting the gas within the tank. Refer to 5810B/5820B Series and the Safety Selector Valve section.

GAS CONTROL

Regulators provide a means to sequentially direct the gas to utilization equipment such as boilers and engine-generators. Upstream or downstream control may be specified. Refer to 180 or 386 Series for more information.

It is important to note that the Model 180 Series Regulators constantly throttle to maintain set upstream or downstream pressure. The Model 386 Series Regulator remains closed until it's set pressure is reached.

Check valves should be specified in locations where a reversal of flow would damage rotating equipment or upset the system pressure balance. Refer to 211 Series.

SAFETY

Occupational health and safety for the plant and personnel is critical when designing a biogas system. Biogas becomes explosive when mixed one volume of gas with 5-20 volumes of air. Proper measures must be taken to ensure that equipment is installed to avoid the possibility of an explosion. Some important factors to consider are:

1. Flame arresters should be installed as close to the source of ignition as possible. Varec Biogas arresters can be located a maximum of 15 feet upstream of the ignition source when used in accordance with UL standards.
2. A flame arrester should be specified in areas where there is a possibility of air ingress off relief valves and vents, as an example. Where there is an open flame or possible sparking, e.g., flares, boilers or engine-generators, additional protection utilizing thermal bypass valves and pressure (explosion) relief valves should be specified along with the flame arrester. Refer to 430 Series, 450 Series and 7100B Series.
3. It is important to check with local building codes, Occupational Health and Safety Association (OSHA) standards, and Fire Protection Codes when determining an installation site for waste gas burners or enclosed flares and related equipment.
4. All diaphragm-operated valves, manometers, and other devices which might vent gas when installed indoors should have provision for vent lines terminating outside the building. A flame check should be specified for installation on vent lines. Refer to 5200 Series.
5. Regular inspections should be made for pressure and vacuum relief devices, flame arresters, and drip traps to ensure proper operation. Periodic maintenance is required for efficient overall performance.

## Extreme Weather Conditions

COLD WEATHER CONDITIONS

1. The gas train and equipment installed outdoors must be insulated. Heat tracing should also be considered. Biogas is wet and dirty, and condensate will have a tendency to freeze in cold weather conditions. This lowers plant efficiency.
2. The pressure-relief regulator (386 Series Back Pressure Regulator) installed on the waste gas burner train should be either:
   a. Installed indoors to ensure proper operation of the pressure sensing line. The sensing line tap-in on the main gas line should be at least 10 feet away from the regulator.
   b. If installed outdoors, provisions should be made to protect the regulator from cold weather. A special insulating jacket can be specified. Heat tracing should also be considered. In extreme cold weather conditions, the sensing line tubing should be insulated and/or heat traced.

   Refer to 386 Series and Insulating Jacket literature for further information.
3. Since the flame arrester or flame trap assembly is recommended for installation within 15 feet of the burner, and will typically be located outdoors, a special insulating jacket can be specified. Heat tracing should also be considered in extreme cold weather conditions. Refer to Insulating Jacket data sheets for further information.
4. The pressure-vacuum relief valves installed on top of a digester cover should be specified with the “all-weather” feature. This includes special anti-freeze coating applied to the seat ring tip, pallet periphery and stem and guide posts. In addition to specifying the “all-weather” feature, the pressure-vacuum relief valve and flame arrester should be:
   a. Provided with a special insulating jacket. Refer to Insulating Jacket literature for more information.
   b. Installed in an insulated or heated shelter or enclosure, with a pressure relief pipe-away option. The pipe-away option allows biogas to be relieved to the atmosphere through a pipe connection one size larger than the process connection. The heated or insulated shelter should have enough ventilation to meet vacuum relief requirements. Refer to 5810B/5820B Series for more information.
5. Drip traps should be located indoors wherever possible. If located outdoors, they should be insulated against freezing. Refer to 246 Series, 247 Series and Insulating Jacket literature for further information.

HUMID CONTROL

1. Field paint a corrosion-resistant coating on equipment that is manufactured with fabricated carbon steel.
2. Consider utilizing stainless steel hardware (nuts and bolts) on equipment to prevent rusting. Rusted hardware can be difficult to maintain.

EMERGENCY RELIEF

A biogas system should have two methods of relieving excess gas to the atmosphere.

Method 1: FLARING

The waste gas burner is used to safely combust the biogas and reduce irritating odors. The pipe train to the waste gas burner should consist of the following:

1. A back pressure regulator valve with a flame arrester and thermal bypass shut-off valve. Refer to the 5000, 386, and 440 Series for information.
2. A pressure (explosion) relief valve. The pressure (explosion) relief valve is intended to relieve an overpressure condition or pressure shockwave in the pipe caused by a flame flashback. A pressure shockwave results upon ignition and travels ahead of the flame in the pipe. As the flame travels through the pipe, it increases in velocity. At the point where the flame ignites the pressure shockwave, a detonation or explosion occurs. The pressure (explosion) relief valve eliminates the potential for an explosion or detonation from occurring. The installation of a pressure (explosion) relief valve can be eliminated if the flame arrester will be installed within 15 feet of the waste gas burner in accordance with UL recommendations. Refer to 7100B Series.
3. Waste gas burner. Refer to the Burners & Flares section.

IMPORTANT

Consult your local air pollution authorities for information on emission requirements before specifying the type of waste gas burner to use. In cases where stack emissions are regulated or where visible flame is unacceptable, an enclosed flare may be specified. A gas pipe train leading to Enclosed Flares differs slightly from what is described here.
Refer to 244E or 249 Series for more information.

4. A drip trap should be installed on the 1/2’” NPT connection provided with the flame arrester if the flame arrester will be installed on a horizontal pipe run. When the flame arrester or trap assembly is installed vertically, then provisions should be made to install drip trap on the lower point of the gas piping to the waste gas burner. Refer to 246 or 247 Series for more information.

## **Emergency Relief** (Cont'd)

Method 1: FLARING (Cont'd)
In cold weather conditions, and in cases where it poses difficulty in installing a relief valve and flame trap assembly as one unit within 15 feet (4.5 meters) of the waste gas burner, the following is the recommended installation:

1. A back pressure regulator should be installed indoors so the cold weather does not affect its pressure sensing line. There are no distance constraints when installing a back pressure regulator on the gas train to the waste gas burner. Refer to 386 Series.

   TIP
   The pressure sensing line of the back pressure regulator will provide more accurate readings when installed further away from the waste gas burner.

2. A flame trap assembly should be installed within 15 feet of the waste gas burner per UL requirements. Refer to 430 and 450 Series for further information. In cold weather conditions, it is good practice to insulate the flame trap assembly. Refer to Insulating Jacket data sheets for further information.

The waste gas burner pipe train should be sized to handle the maximum amount of gas produced by the digester.

It is important that the burner pilot remains continuously lit while the biogas is flaring to ensure safe disposal. The pilot gas supply can either be biogas, natural gas or propane. Utilizing natural gas or propane ensures a more reliable pilot and is especially critical in areas with high winds. Auto-start ignition and pilot flame monitoring are recommended features. Refer to the Flare Section of this catalog when choosing the type of burner suited for your application.

Method 2: PRESSURE AND VACUUM RELIEF ON DIGESTER OR GAS HOLDER COVER
The second means for emergency relief is through the installation of pressure and vacuum relief valves on the digester cover, or biogas holder. A minimum of two pressure/vacuum relief valves with flame arresters are recommended. Each set of two should be installed with a Safety Selector Valve, as shown on the diagrams provided. The Safety Selector Valve provides a means to isolate one set of equipment while performing maintenance on another. Refer to 2010B/2020B, 5810B/5820B and Safety Selector Valve data sheets for more information.

DIGESTER ACCESS
Digester contents are often sampled to provide plant operators an evaluation of process efficiency. At least two 8" (200 mm) quick-opening sampling hatch covers should be mounted on sampling wells on each digester cover. When digesters are cleaned, roof access is required. It is advisable to provide at least two large diameter gas-tight manholes with quick-opening covers. Refer to 42, 4310, 220, 220W, 400W, and 220VP for more information.

PROCESS MONITORING
To successfully operate the biogas system, gas production and line pressure must be carefully monitored.

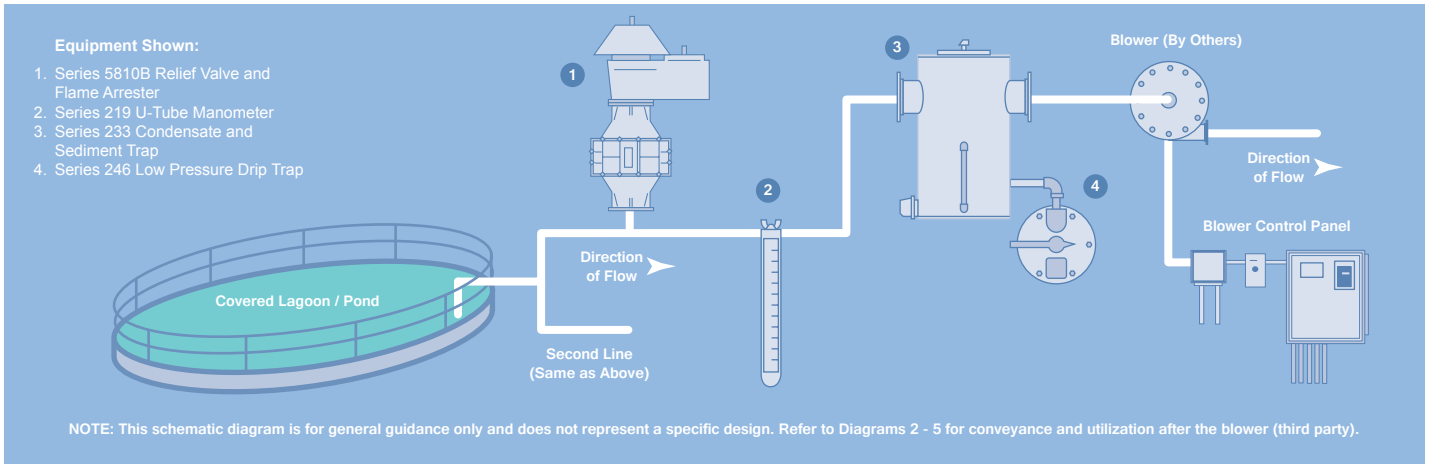
When floating digester covers are used, the Digester should be equipped with position indicators. Cover level may be transmitted to grade or control room by mechanical or electrical means. High and low level alarms should be considered to protect the covers from structural damage. Refer to 2592 Series.

Manometers should be installed in each pipe train to monitor the system pressure. Gas flowmeters should be located at each digester, and in the main header. Meters should also be installed to measure the flow to each biogas utilization equipment. Refer to 217 Series and 219 Series for more information on manometers.

## System Diagrams

### COVERED LAGOON / POND APPLICATIONS

The use of covered lagoons or ponds in place of anaerobic digesters is another method of wastewater treatment. This biogas handling system is similar to systems utilizing anaerobic digesters, except with covered lagoons or ponds, a blower is normally required to boost the pressure of the gas collected from the lagoon or pond.

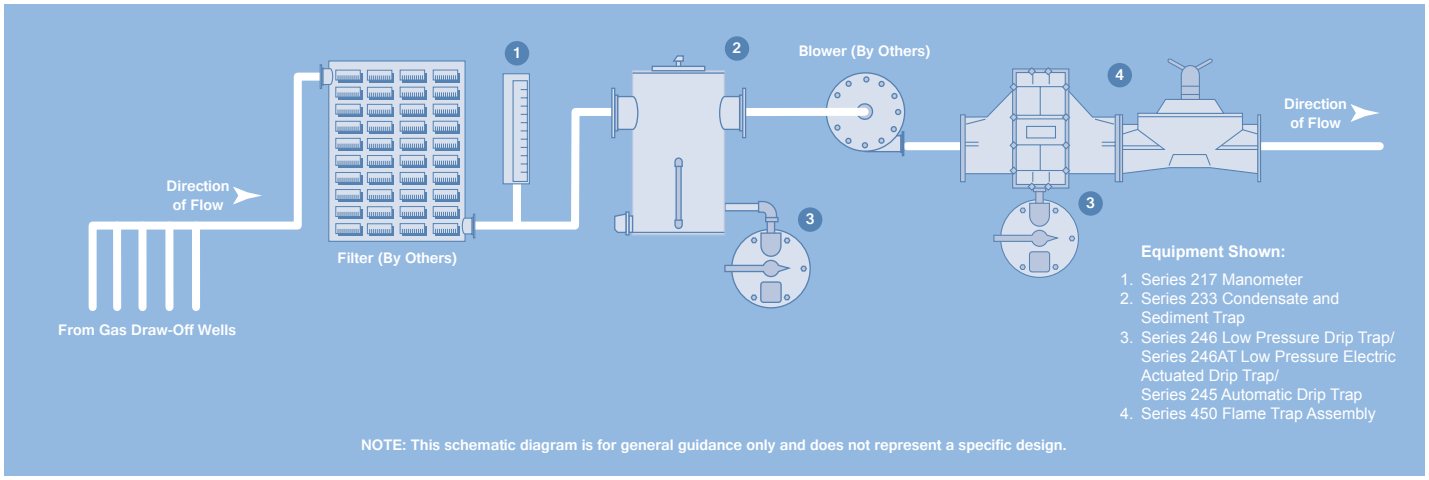



NOTE: This schematic diagram is for general guidance only and does not represent a specific design. Refer to Diagrams 2 - 5 for conveyance and utilization after the blower (third party).

### LANDFILL GAS APPLICATIONS

The Landfill Gas (LFG) handling system is similar to a biogas handling system with an anaerobic digester or a covered lagoon / pond. Landfill Gas composition is generally more susceptible to fluctuations in Btu content. LFG may be collected and flared. In larger land fills, the gas may be utilized.

In landfills, a compressor is specified to draw-off gas from the gas collection wells. The compressor suction is generally of large diameter to minimize the vacuum required to obtain the gas. Some leachate treatment systems use an aerobic reactor which produces a digester-type gas.

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