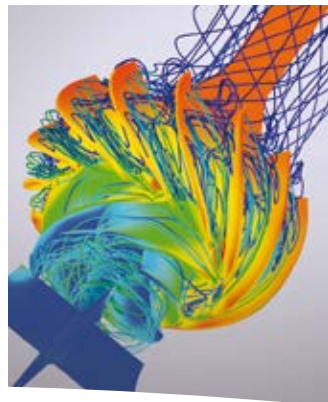


***SIHI® Gas separation  
by using membranes***





## **Pump Supplier to the World**

*Flowserve is the driving force in the global industrial pump marketplace. No other pump company in the world has the depth or breadth of expertise in the successful application of pre-engineered, engineered, and special purpose pumps and systems.*

### **Life Cycle Cost Solutions**

Flowserve provides pumping solutions that permit customers to reduce total life cycle costs and improve productivity, profitability and pumping system reliability.

### **Market-Focused Customer Support**

Product and industry specialists develop effective proposals and solutions directed toward market and customer preferences. They offer technical advice and assistance throughout each stage of the product life cycle, beginning with the initial inquiry.

### **Broad Product Lines**

Flowserve offers a wide range of complementary pump types, from pre-engineered process pumps to highly engineered and special purpose pumps and systems. Pumps are built to recognized global standards and customer specifications.

Pump designs include:

- Single-stage process
- Between bearings single-stage
- Between bearings multistage
- Vertical
- Submersible motor
- Positive displacement
- Vacuum & Compressor
- Nuclear
- Specialty

### **Product Brands of Distinction**

*ACEC™ Centrifugal Pumps*

*Aldrich™ Pumps*

*Byron Jackson® Pumps*

*Calder™ Energy Recovery Devices*

*Cameron™ Pumps*

*Durco® Process Pumps*

*Flowserve® Pumps*

*IDP® Pumps*

*INNOMAG® Sealless Pumps*

*Lawrence Pumps®*

*Niigata Worthington™ Pumps*

*Pacific® Pumps*

*Pleuger® Pumps*

*Scienco™ Pumps*

*Sier-Bath® Rotary Pumps*

*SIHI® Pumps*

*TKL™ Pumps*

*United Centrifugal® Pumps*

*Western Land Roller™ Irrigation Pumps*

*Wilson-Snyder® Pumps*

*Worthington® Pumps*

*Worthington Simpson™ Pumps*



## Membrane technology ... the innovative solution

*In process technology, there are various techniques that can be used for separating gases. One successful field is membrane separation technology. Individual components can be separated from gas mixtures using membranes. For example, pollutants can be separated from the air to meet national regulations on exhaust air and/or recover valuable components with the aim of feeding them back into the production process.*

SIHI® has not only manufactured high-quality vacuum and compressor systems for 90 years, but also has more than 20 years' worth of experience in developing customer-specific solutions for waste-air purification and the recovery of solvents using membranes. Application-oriented knowledge and advice from our expert team provide excellent foundations for this process, as well as problem-free integration and long-term reliability of the module.

Continuous innovations guarantee that our customers can benefit from the advantages of new developments. Our experts will be happy to advise you about new possibilities for separation and recovery, and they also make use of external resources in order to provide you with an optimal solution.

Project-based expertise: Our competence centre will design processes together with you that are optimized for your needs. To do so, we will normally use current process simulation software in order to find the optimal solutions for you and then consult with you to decide which approach is right for you.

DIN, ISO, ASME, API and NACE are regulations that we have in-depth knowledge of, and we can ensure that our units are built to these specifications. We would also be happy to investigate other national guidelines and build systems that adhere to these.

### Industries/Markets

- Chemistry
- Petrochemicals
- Fuel depots
- Pharmaceuticals
- Foodstuffs
- Environmental technology

### Typical applications

- Solvent recovery
- Monomer recovery
- Product recovery
- Natural-gas conditioning
- Gas loop processing
- Vapour recovery units



**Recovery systems with membrane technology**



**...compact, simple and effective**

Membrane technology is a simple and highly effective technology used to recover solvents or ensure adherence to emissions limits (for example: Germany's National Regulation – TA Luft) for exhaust gases. The highly effective separation process ensures that the pure substance can be recovered without the need for subsequent regeneration and/or cleaning.

The desired components permeate through the membrane and can therefore be recovered, while the scrubbed inert gas can be released into the atmosphere or retained for further use.

**How does a membrane work?**

Membrane modules have been specially developed to ensure effective and safe separation, with the aim of separating, recovering or utilizing solvents from process gases. Process gases and/or vapours are guided to a special polymer membrane. The components to be separated permeates through the membrane and can therefore be recovered, while the scrubbed inert gas remains on the high pressure side and can be released into the atmosphere or retained for further use.

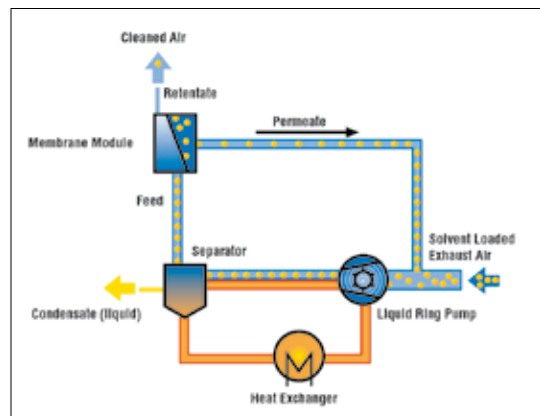
The result is a simple and highly effective system for recovery or reduction of emissions. One example is the separation of volatile organic compounds from permanent gases such as N<sub>2</sub> or air.

**Components that can be recovered**

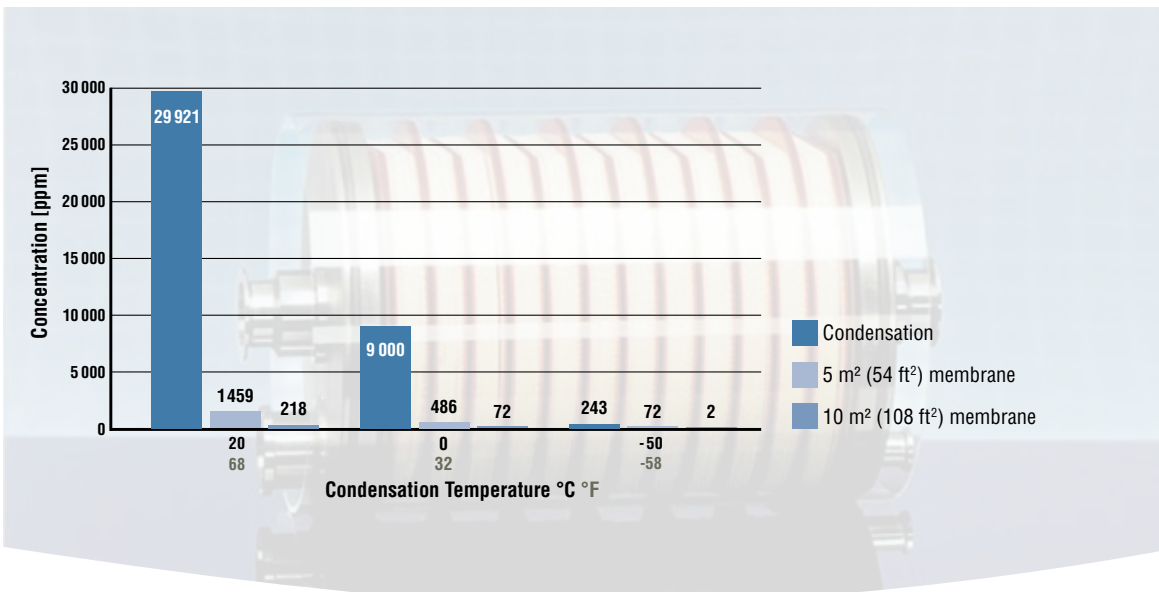
- Vinyl chloride monomers
  - BTX
  - Hexane
  - Ethylene and propylene derivatives
  - Fuels
- And many more ...

**Benefits**

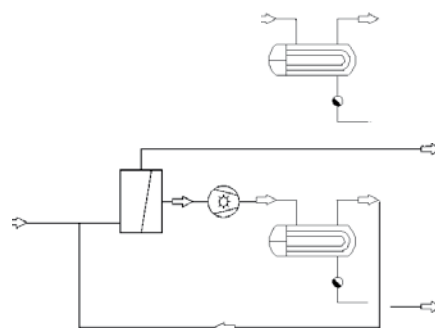
- Simple, compact
- Long lifetime
- High level of efficiency
- No regeneration necessary
- Pure material recovery
- Suitable for several solvents and monomers, as well as a number of organic components



**More economical than cryo-condensation**

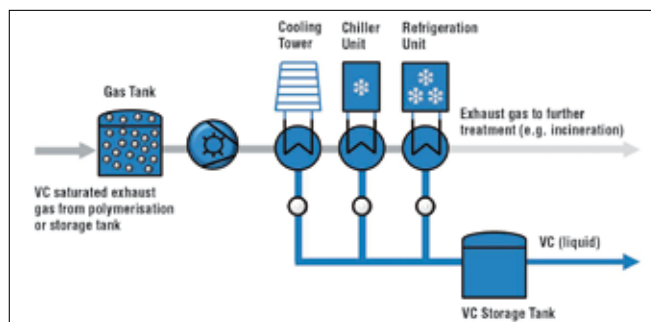


One advantage of the membrane technique versus pure condensation is the fact that the membrane process can be carried out at higher cooling-water temperatures. With a membrane, pure substances can be obtained at normal condensation temperatures that would render cryo-condensation necessary if no membrane were used. Membrane technology allows you to reduce your operating costs and recover your product!



**Conventional VCM recovery**

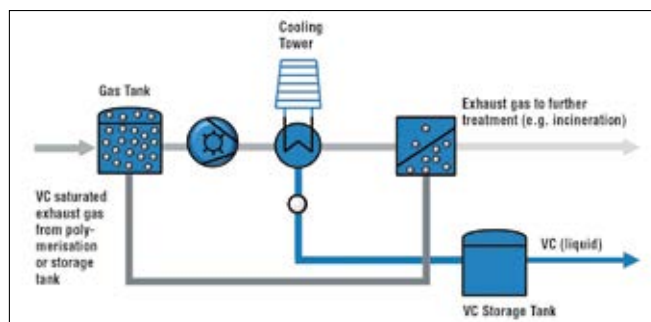
One example of this is VCM (vinyl chloride monomer recovery). The VCM-saturated exhaust gas, which comprises mainly monomers, is fed through a compressor and multiphase condensation process. Condensation temperatures increase incrementally from the first to the last stage. The first stage is performed at normal cooling-water temperatures, while the subsequent stages have discharge temperatures that are considerably below freezing.



**VCM recovery with membranes**

The membrane replaces the multistage condensation process and therefore reduces operating costs in production. The investment has a payback period of less than one year for converted production processes.

With a new installation, the condensation stage, membrane and compressor can be coordinated optimally right from the start. In this case, the payback period is approximately six months.

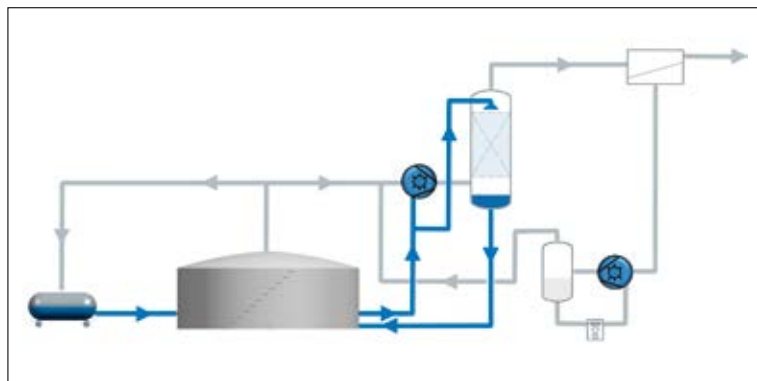


*More environmentally friendly than adsorption*



*A membrane module comprises the process of cleaning exhaust gas and product recovery.*

There are no disposal costs for contaminated adsorbents. Solvents are condensed and separated in order to feed them back into the production process. Monomers are separated from the exhaust gas and can be fed back into the polymerization process. No expensive equipment is required, and there are no problems with high enthalpies of adsorption.



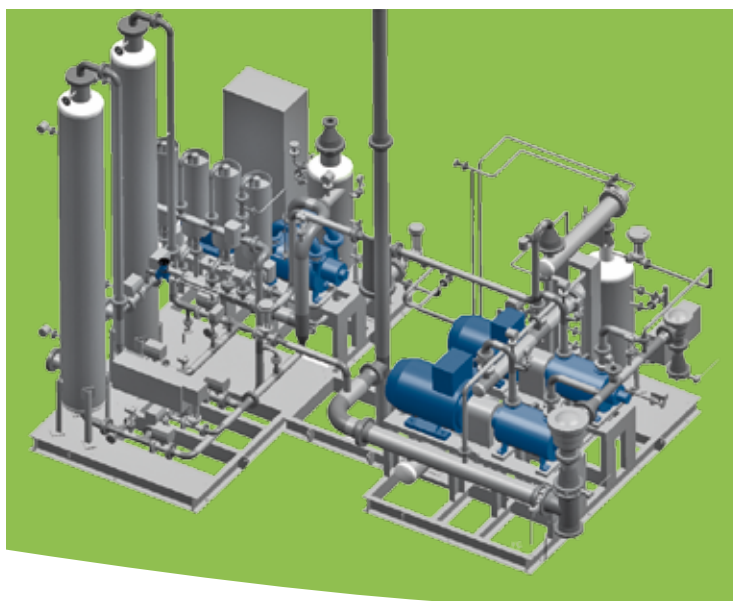
A membrane module has a small footprint and can be used immediately after installation. The membrane is a safe and cost-effective alternative. One example is the vapour recovery unit (VRU) in storage tanks.

Membrane modules for vapour recovery work according to the following principle: Intake and compression of the exhaust gas, adsorption of the vapour in a gas scrubber and separation of the remaining hydrocarbons using membranes. If liquid ring machines are used in the modules, the compression pressure for the gas scrubber and membrane is between three and six bars.

This pressure is maintained right up to the discharge from the membrane. This is to ensure that the gas scrubber achieves the optimal cleaning results and also because the membrane requires the positive pressure in order to obtain the required pure substances. For this reason, the membrane is supported with an additional vacuum pump.

Vapours to recovery modules	Possible adsorption liquids (in the tank)
Petrol	Petrol
Petrol components (e.g. MTBE)	Petrol
Various hydrocarbon compounds	Naphtha, pyrolysis gasoline
Aromatic compounds	Aromatic compounds
Pure individual components (e.g. hexane)	Similar components

**Hybrid plant with the smallest exhaust concentrations**



*A successful combination of two processes: the hybrid plant with a membrane stage and pressure swing adsorption (PSA).*

One example of a successful combination of two processes is that of membrane technology and adsorption technology. This process combination is advantageous primarily because recovery using a membrane can be highly cost-effective.

The stream of exhaust gas from the membrane contains very low residues of the incoming feed. Any water contained within is also separated by the membrane. This ensures that a constant dry stream of exhaust gas with a consistent low concentration is fed through to the adsorption stage, where it undergoes further cleaning.

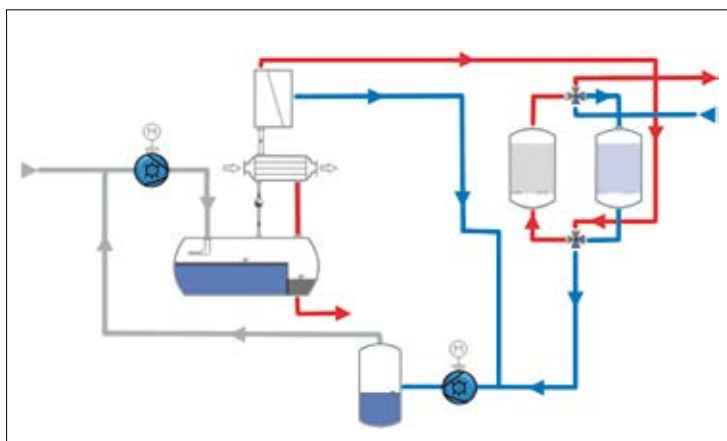
While one adsorber cleans the exhaust gas from the membrane stage, a second adsorber undergoes the regeneration process and is desorbed with the help of purging gas and negative pressure in the installed vacuum pumps. The volume of purging gas required for this is a fraction of the overall volume of gas fed into the system as a whole.

The adsorber is therefore fed a constant, dry, pre-scrubbed stream of exhaust gas, regardless of the original concentration of the gas. This prevents problems such as high temperatures in the activated carbon bed caused by high input concentrations and the activated carbon being saturated by water.

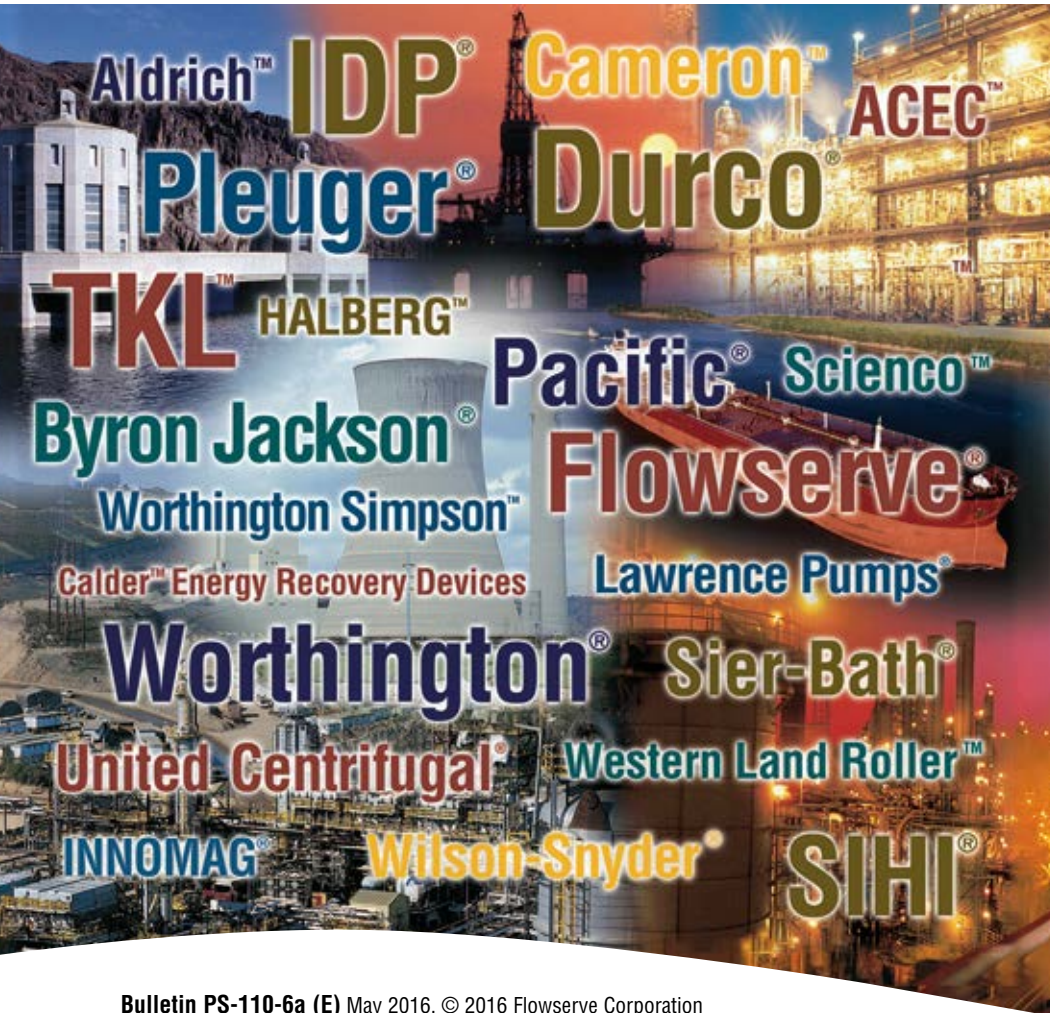
The operational safety and ease of use when starting up and shutting down this hybrid module has contributed to its success. A hybrid module achieves outflow concentrations in the single-digit ppm range.

**Benefits**

- Achieves outflow concentrations in the single-digit ppm range
- Hybrid module has smaller footprint than a PSA
- No hotspots due to high intake concentrations are possible as the membrane takes over the function of “preliminary cleaning”
- Easy to use even when starting up and shutting down







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