User Guide

PTFE-TMCS-CONTACTOR

Version number: COOP 202409.01

Anhui Cooperate Environment Technology Co., Ltd.

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1、Safety Information

Please read and adhere to all safety information, warnings, and instructions provided in this manual. Failure to do so may result in serious injury and property damage.

The PTFE-TMCS membrane contactors are designed for use in Transmembrane Chemisorption (TMCS) processes, where gases are removed and absorbed into a liquid phase and then converted by a chemical reaction. These membrane contactors can also be used to eliminate dissolved gases and bubbles from compatible liquids or to introduce gases into a liquid stream.

Please do not use the product or any extractable or leachable substances from the product in any way that may involve its incorporation into a medical device, drug, cosmetic, food or drink additive or supplement, or infant formula. Additionally, refrain from using them in applications involving life-sustaining medical equipment or prolonged contact with internal bodily fluids or tissues.

A、WARNING

- Do not exceed maximum operating pressure or temperature limits.
- Implement workplace safety risk controls according to local applicable laws and regulations.
- Always use appropriate personal protective equipment (PPE) when installing, servicing, operating, cleaning, or disposing of the membrane contactor.
- All plumbing should be done in accordance with local regulations and code.
- To prevent the buildup of pressure inside the membrane contactor, do not block or valve off all gas/vacuum ports during operation or downtime.
- Ensure that chemically compatible materials of construction are used within the system.
- Always verify proper connections within the membrane contactor system.
- Never modify or alter the membrane contactor. Only or parties authorized in writing may make changes/repairs to the equipment.
- Inspect the membrane contactor prior to cleaning or installation. Use only replacement parts supplied by for this product.
- Inspect the membrane contactor to ensure there are no leaks, cracks, or other signs of damage on the membrane contactor, gaskets, tubing, or piping.
- Make sure the system is well-ventilated and that any gases used or generated during membrane contactor operation, cleaning, and drying are properly discharged, in compliance with building codes and regulations.
- Do not introduce explosive, flammable, toxic, or oxidizing liquids or gases in dangerous concentrations into the membrane contactor or the system.
- Avoid over-pressurization of liquid and gas by installing proper pressure relief valves and safety systems.
- Install appropriate safety equipment, such as flange covers and skid enclosures or shielding, to protect against possible spraying or release of acid under pressure.
- Do not try to move the system while it contains liquid or while it is in operation. Use lifting equipment rated for the system's weight and ensure that the system is stable, level, and properly secured to prevent any movement that may cause injury or damage.
- Use shims to level the system if necessary.

B、Storage and Transport of Membrane Contactor

Careful handling is required during transportation to avoid dropping, hitting, or impacting the membrane contactor. Please ensure that Membrane Contactors are stored in a dry environment. It is preferable to store them in a sealed plastic bag or shrink wrap to prevent contaminants from entering. Store the contactors at temperatures below 50°C (122°F). Always store them above freezing temperatures; if they have been stored at low temperatures, allow them to come to room temperature before use.

2、Technology Overview

PTFE offers exceptional resistance to oxidation and corrosion and performs better at high temperatures than PP. Despite being challenging to process and shape, its superhydrophobic property makes it an excellent material for producing degassing membranes. 's PTFE-TMCS membrane contactor can withstand oxidants such as chlorine, peroxides, ozone, and other oxidizing agents. It is widely applicable for degassing or transmembrane chemisorption in industrial settings.

A、 PTFE Membrane Contactor Description and Design

PTFE-TMCS membrane contactor utilizes a specially woven pure PTFE hollow fiber membrane. In this process, wastewater containing volatile compounds flows through the inside or outside of the hollow fiber membrane. In contrast, an absorption liquid, typically an acidic or alkaline aqueous solution, flows through the outside or inside of the membrane, respectively.

For instance, if the acidic gas to be removed is hydrogen sulfide, an alkaline absorption liquid like sodium hydroxide is used. Conversely, if the volatile substance is alkaline, such as ammonia, an acidic absorption liquid, such as sulfuric acid solution, is employed. The volatile gas in the wastewater diffuses from the micropores of the hollow fiber membrane to the absorption liquid due to the concentration difference. It immediately reacts with the acid or alkali in the absorption liquid to neutralize, resulting in the concentration of volatile substances in the absorption liquid approaching zero.

Therefore, the concentration difference of volatile substances on both sides of the hollow fiber membrane drives the volatile substances in the wastewater to continuously diffuse into the absorption liquid, effectively removing them.

Figure 1. Membrane Contactor

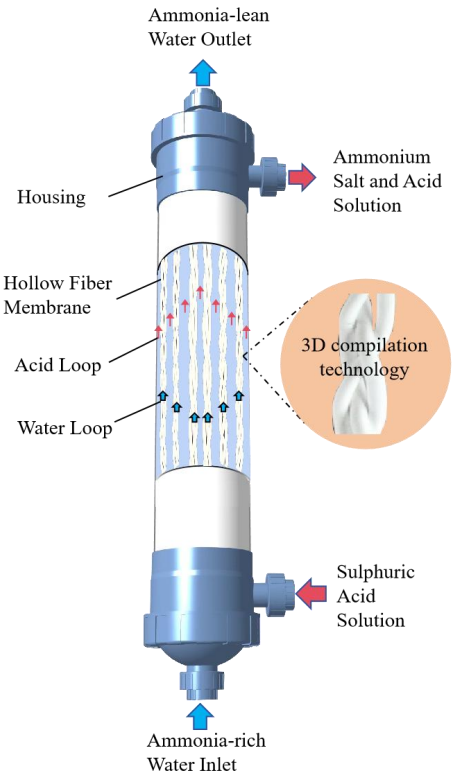
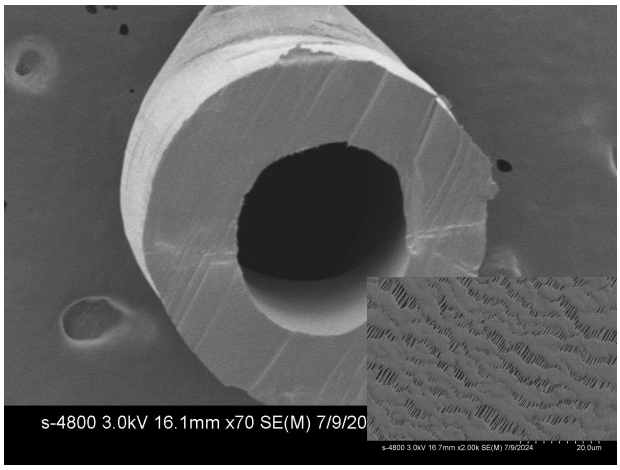
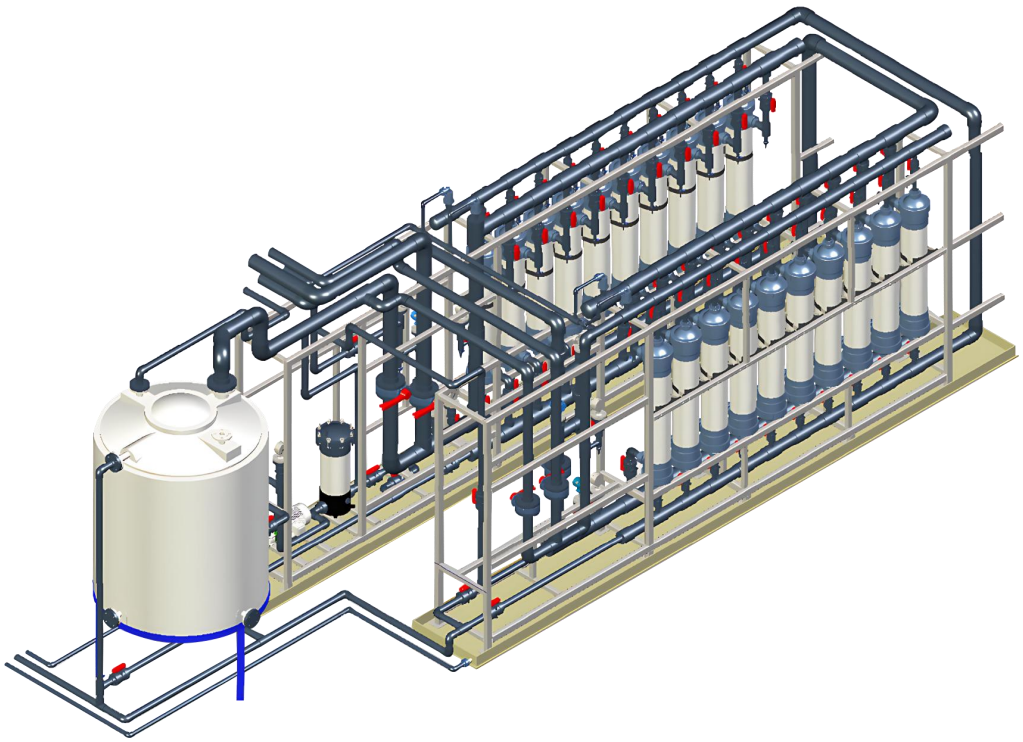


Figure 2. Hollow Fiber Membrane(SEM)



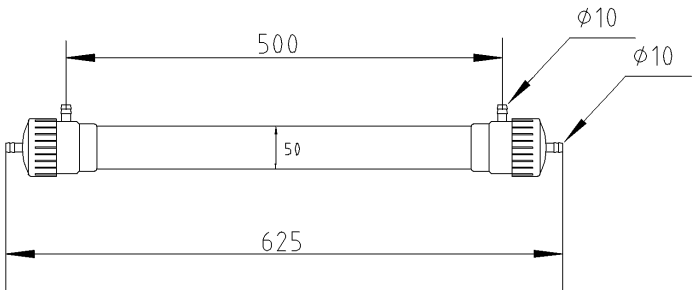
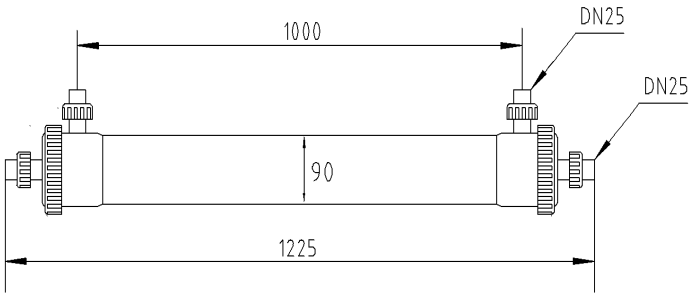
Outer diameter of the membrane filament and 3000 times the electron microscopy of the outer surface

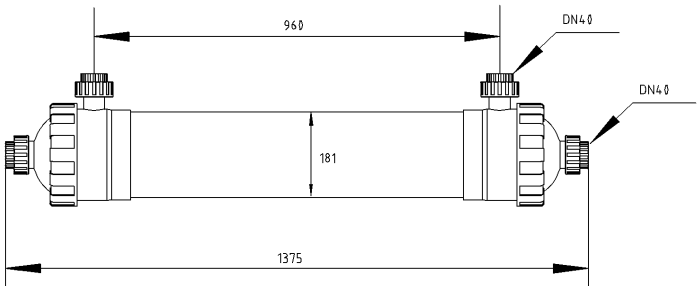
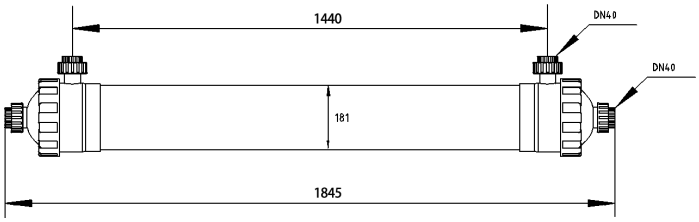
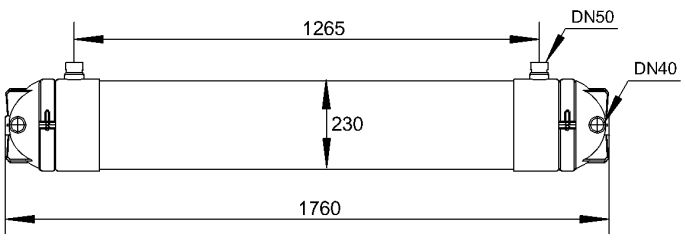
Figure 3. PTFE-TMCS Membrane System



B、PTFE-TMCS Product Range

Table 1: Typical recommended liquid flow rates for TMCS		
PTFE-TMCS membrane contactor	Feed water stream (lumen side)	Absorption liquid (shell side)
PTFE-TMCS-2020	5-20L/h	20-80L/h
PTFE-TMCS-4040	50-180 L/h	200-720 L/h
PTFE-TMCS-8040	400-1000 L/h	1600-4000 L/h
PTFE-TMCS-8060	500-1500 L/h	2000-6000 L/h
PTFE-TMCS-X60	600-1800 L/h	2400-7200 L/h

Table 2.Membrane contactors size & membrane area		
Membrane contactor	**Membrane area**	**Dimensional drawings**
PTFE-TMCS-2020	1.7 ㎡	
PTFE-TMCS-4040	12 ㎡	

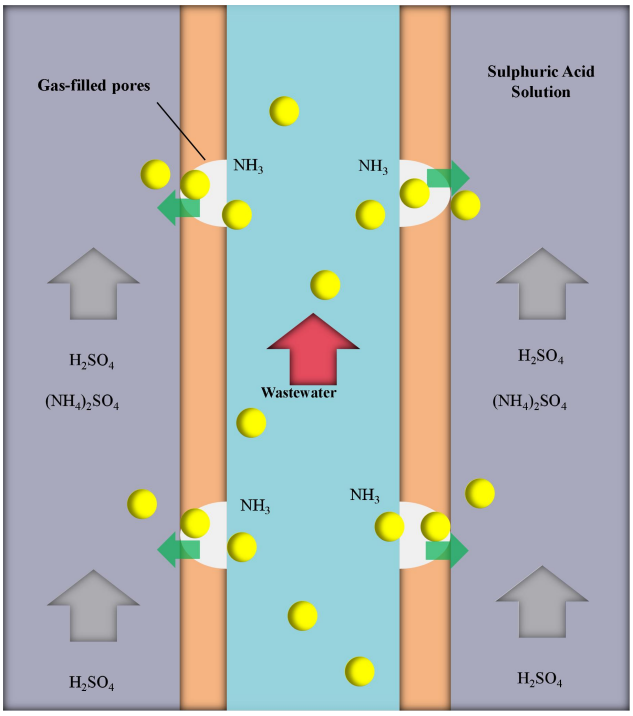
Membrane contactor	Membrane area	Dimensional drawings
PTFE-TMCS-8040	65 ㎡	
PTFE-TMCS-8060	97.5 ㎡	
PTFE-TMCS-X60	120 ㎡	

C、TMCS Mode for Ammonia Abatement (Removal)

The Transmembrane Chemisorption (TMCS) is an effective operating mode for membrane contactors that can be utilized for various gas transfer applications. Using ammonia as an example, this mode involves physically removing ammonia from feed water, allowing it to diffuse across the membrane wall, and then chemically reacting with a liquid acid stream. This process, also known as ammonia abatement, is a valuable technique.

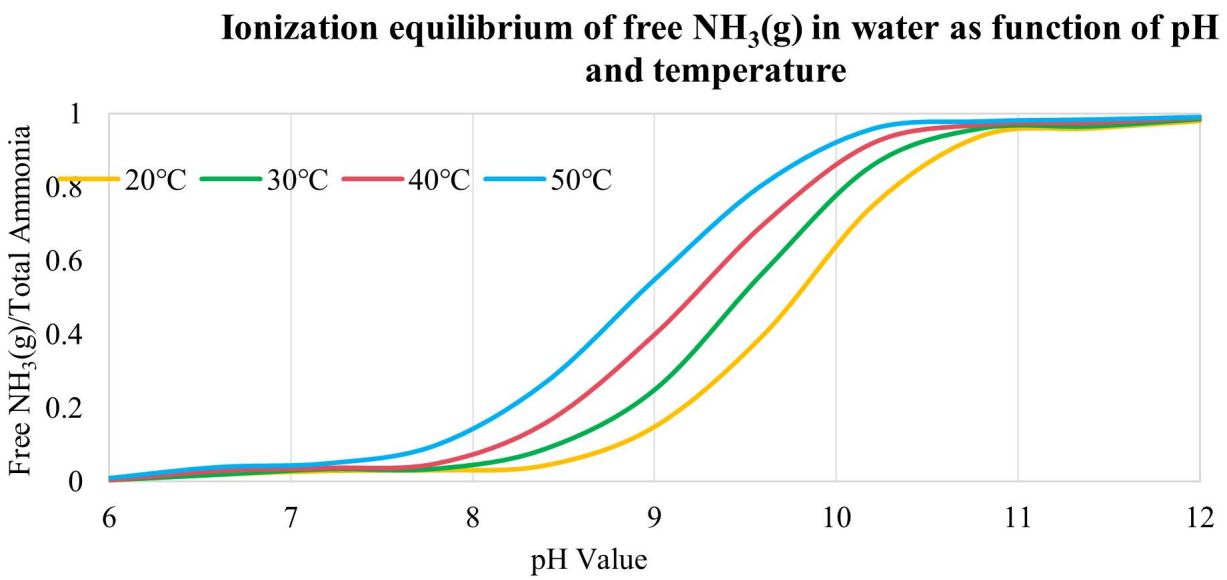
The two aqueous liquid phases are separated by the wall of the hydrophobic microporous membrane. The feed water, containing ammonia, flows inside the hollow fibers (lumen side), while an acid solution (with pH < 1-2) flows in a counter-current direction outside the hollow fibers (shell side). Ammonia gas passes through the air-filled pores and reacts with an acid, such as sulfuric acid, to form ammonium salt. The driving force for ammonia transfer is the concentration difference between the feed water phase and the acid phase.

Figure 3



Both the pH and temperature influence the concentration of free ammonia gas in water. When the pH is higher than 10.5, and the temperature exceeds 35°C, nearly 98% of the ammonia exists as free ammonia (NH_3 gas), which can permeate through the pores of hollow fibers. It's important to note that only NH_3 gas, not the ammonium ion (NH_4^+), can diffuse across the microporous membrane. To promote the formation of free NH_3 gas, it may be necessary to elevate the pH of the feed water by adding a base like sodium hydroxide (NaOH). The base required will depend on the initial pH level and the feed water temperature.

Figure 4



Like other gas transfer processes, the feedwater temperature affects the removal of ammonia. As the temperature rises, the gas solubility decreases, and the gas diffusivity increases. This means that higher feed water temperatures result in a more significant transfer rate of ammonia. However, it's essential to be mindful that the transfer rate of water vapor also increases at higher temperatures, leading to a dilution effect in the acid phase.

In the TMCS process, the driving force for ammonia transfer across the membrane increases with a higher concentration of free ammonia in the feed water, assuming all other parameters remain constant. Consequently, ammonia transfer rates are more favorable at higher inlet ammonia concentrations and less favorable at deficient inlet ammonia concentrations.

An acid solution is instrumental in maximizing the ammonia driving force. For instance, a sulfuric acid solution rapidly reacts with ammonia gas to form ammonium sulfate, effectively reducing the ammonia concentration to zero in the acid phase. The maximum theoretical concentration of ammonium sulfate for the TMCS process is the saturation solubility of the salt, which is 43.5g/100g water at 20°C. However, the highest achievable concentration of ammonium sulfate in the TMCS process is contingent upon the inlet ammonia level in wastewater, the inlet acid concentration, and the amount of transferred ammonia and water vapor.

It's crucial to avoid oversaturation or salt precipitation at the acid-membrane interface due to local concentration gradients, as this can lead to scale formation on the membrane surface and potentially obstruct the flow in the hollow fiber lumen. The choice of acid will determine the resulting reaction product (salt).

3、Important Information on Product Protection

A、Surface Tension of Wastewater

Surfactants, organic solvents, and temperature can impact the surface tension of wastewater. In the case of membrane contactors, if the surface tension is low, the membrane can become easily wetted, leading to the membrane contactor's failure. Therefore, it is essential to monitor the surface tension of wastewater to ensure the stable operation of membrane contactors.

Table 3.Surface tension affected by temperature

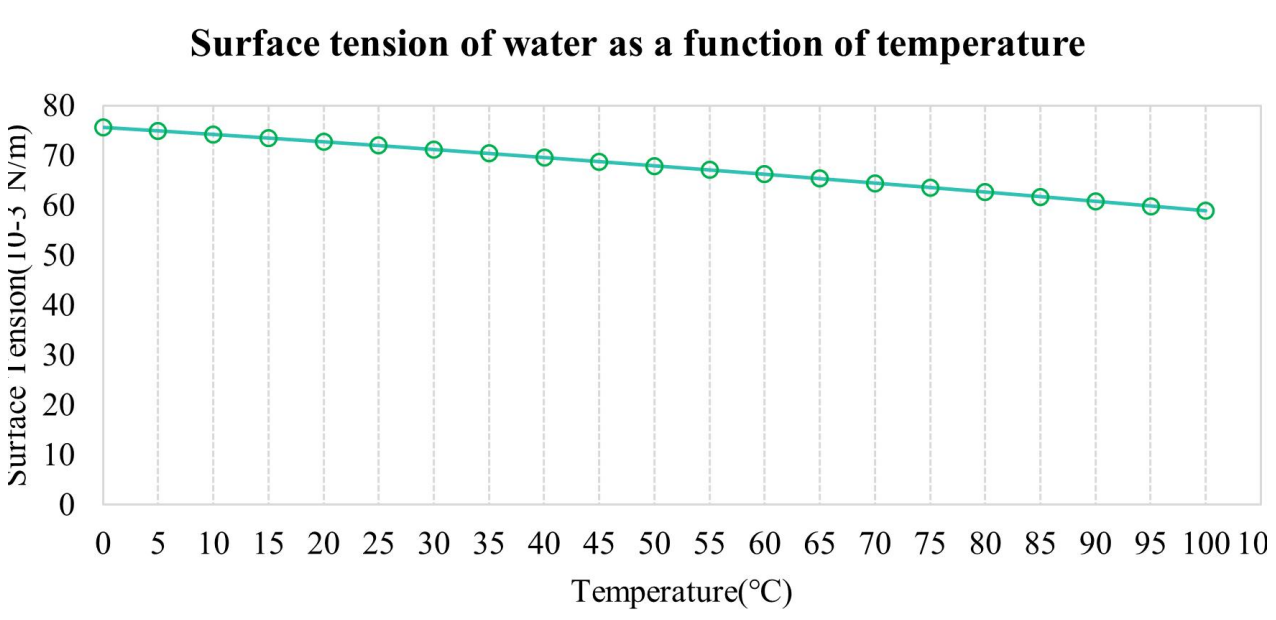
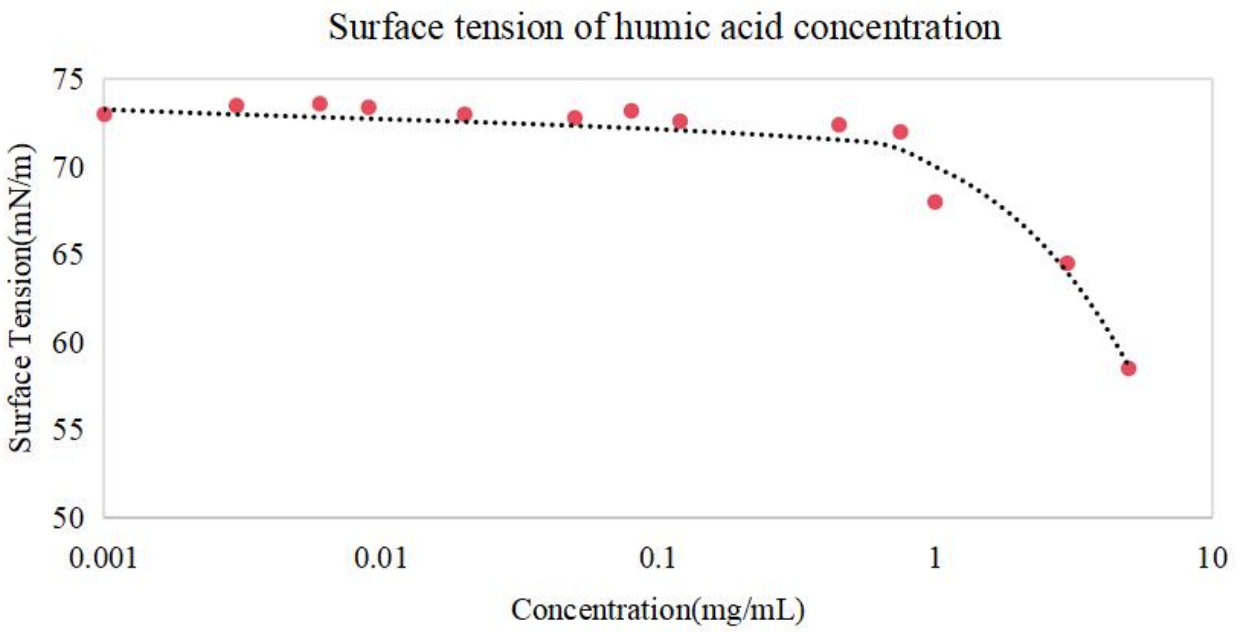


Table 4.Surface tension affected by organic solvents



B、System Pressure and Temperature

To prevent the membrane contactor from getting wet or damaged, it is essential to run the system at a lower pressure and avoid sudden pressure changes. The operating pressure on the wastewater or the absorption liquid side should be kept below 1 bar, and lower pressure is preferable. It is recommended that the membrane contactors have no more than three stages. Under normal conditions, the operating pressure for a three-stage membrane assembly won't exceed 0.5 bar. If the pressure increases during operation, it indicates that the membrane contactors are contaminated or blocked and need cleaning.

The PTFE-TMCS membrane contactor is available in two different shells. The maximum operating temperature for the membrane contactor with a UPVC shell is 45°C, while the maximum operating temperature for the membrane contactor with a CPVC shell is 85°C. Both membrane contactors should avoid significant temperature changes over a short period during operation.

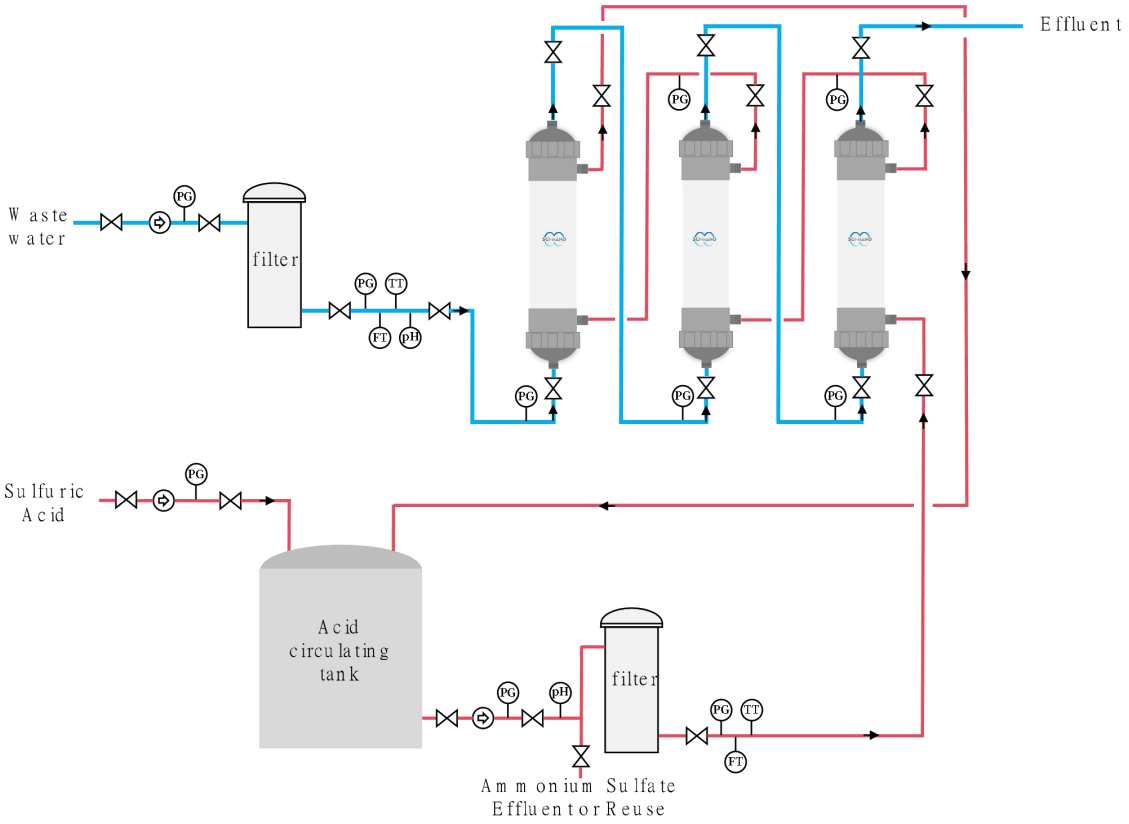
C、Surfactants

The presence of surfactants in water significantly reduces the surface tension of water and causes persistent and cumulative adverse effects on the hydrophobicity of the membrane. Therefore, it is necessary for both the wastewater to be treated and the absorption liquid to be free of surfactants.

4、General System Design & Guidelines

Schematic process diagram of a typical plant for TMCS of ammonia is shown in Figure 5. In this process, wastewater and acid flow from bottom to top through a series of vertically installed membrane contactors on the lumen and shell sides.

Figure 5 Generic P&ID with Three Membrane Contactors in Series for TMCS of Ammonia



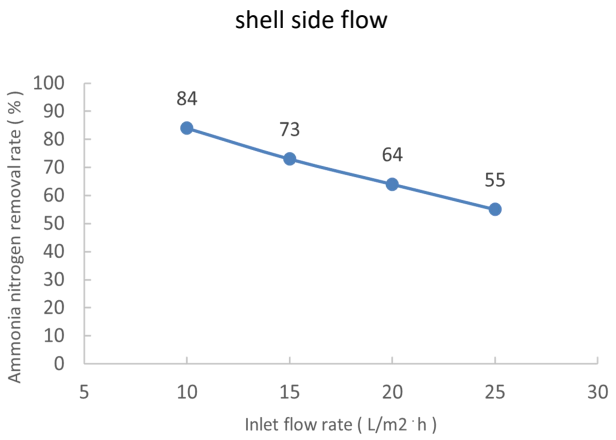
To determine the number of membrane contactors needed, follow these steps: First, divide the amount of wastewater to be treated by the standard flow rate of a single membrane contactor, which is currently calculated based on 10 liters of water per square meter membrane area. Then, the number of stages required in the series will be determined based on a single membrane contactor's ammonia nitrogen removal rate at the standard flow rate.

For example, if you need to treat 240 tons of wastewater containing 2000 mg/L of ammonia nitrogen per day to bring it down to 100 mg/L before discharge, you can calculate the required membrane components as follows: 240 tons divided by 24 hours equals 10 tons per hour, and then 10 tons divided by the standard flow rate of an 8040 component (0.65 T/h) equals approximately 15.38. For safety, you can round this up to 16 per stage.

Each membrane component's ammonia nitrogen removal rate at the standard flow rate is typically between 70% and 90%. Assuming an 80% removal rate, a two-stage series removal rate would be 96%. Therefore, 32 membrane components in two stages can achieve an effluent concentration of 80 mg/L, meeting the discharge requirements.

Table 5 removal rate of ammonia

Table 5.Removal rate of ammonia



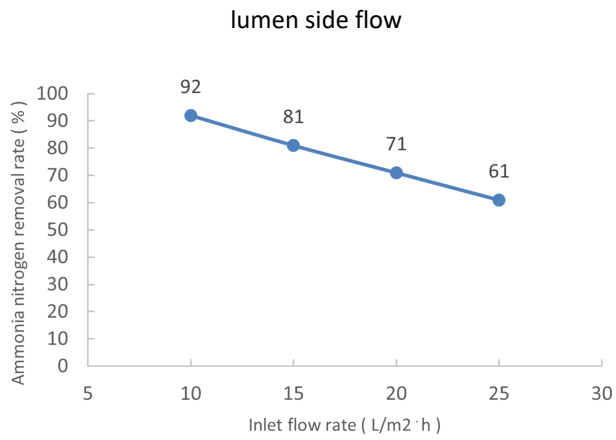


Table 6.Inlet water quality guidelines

Quality Indicator	Units	Recommended Level	Prevention / Control	Cleaning
Total Suspended Solids	ppm (mg/L)	<1	Focculation/MF/UF/NF	No treatment
Particle Size	Micron, absolute rating	≤5 for typical particles	Pre-fltration	Back washing (not for carbon)
Suspended Oil	ppm	≤ 5	Fltration	(hot) Caustic
pH	Units	0.5 – 14		
Silica – Colloidal	ppm	< 10	Antiscalants	Hot caustic
Surfactants	ppm	0		Water/alcohol (>25%) cleaning & drying
Total Hardness	ppm	100 ppm (as $CaCO_3$)	Softening/antiscalants	Acid cleaning

To maintain the pH of the acid absorption liquid between 0.5-2, a metering pump can be utilized to add concentrated acid to water. As there are no other impurities entering the acid absorption liquid, only a 5-micron security filter is required for protective filtration.

Table 7.ideal process parameter for TMCS of ammonia

Operating parameter	Recommended Level	Unit
NH3(g) inlet concentration	> 200	ppm (mg/L)
Wastewater pre-fltration (absolute)	<5 absolute	μm
Temperature range	>35-45 (95-113)upvc shell >35-85 (95-185)cpvc shell	℃ (F
Operating pressure	≤ 0.5	bar
Wastewater stream pH	≥ 11	
Acid stream pH	≤0.5-2	

5、Troubleshooting

Table 8.Troubleshooting Guidelines

Problem Description	Probable Cause	Corrective Action
Outlet ammonia concentration above specification	Membrane contamination/fouling	Clean contactor. Refer to Cleaning Guidelines
		Replace contactors
	Liquid temperature below design specification	Raise temperature or add more contactors
	Liquid flow rate higher than design specification	Reducue flow rate or add more contactors
	Low acid flow rate or concentration	Increase acid flow rate. Use higher acid concentration
	Unequal liquid flow through contactor trains	Verify train flow rate.
		Adjust valves accordingly to equalize flow rates
pressure increase in liquid and/or acid side	Membrane contamination/fouling	Clean contactor. Refer to Cleaning Guidelines
Sudden increase or decreaseof pH in feed water or acid outlets	Membrane leakage/wet out	Drain and remove all liquids. Rinse, clean and dry the contactors. Refer to Cleaning and Storage Guidelines.
		Replace contactors
	Surfactants or oils/fats may have been introduced into contactors, leading to membrane wet out	Drain and remove all liquids. Rinse, clean and dry the contactors. Refer to Cleaning and Storage Guidelines
		Replace contactors

6、Membrane Contactor Cleaning Guidelines

When using membrane contactors for an extended period of time, it's important to monitor the effluent ammonia nitrogen content. If the content increases, immediate detection of the inflow flow rate and ammonia nitrogen content is necessary. If these values remain unchanged, it indicates contamination and reduced performance of the membrane contactor. Chemical cleaning is required to remove pollutants from the membrane surface and prevent the formation of stubborn scaling.Different pollution situations call for different cleaning methods.

Chemical Cleaning Operation Method:

A. Pour the specified amount of cleaning solution into the chemical cleaning tank.

B. Open the inlet valve and reflux valve of the washing system. Start the washing pump and slowly inject water to fill the entire membrane contactor with the cleaning solution for soaking. Once filled, close the washing pump and inlet valve and let it soak for 60 minutes. After soaking, reopen the inlet valve, start the washing pump, and perform cyclic washing on the membrane contactor for 2 hours.

After washing, turn off the washing pump, empty the cleaning solution from the membrane contactor, and connect it to tap water. Rinse forward for 5 minutes to remove the cleaning solution. After rinsing, empty the accumulated liquid and use compressed air for regeneration.

When using chemical agents for cleaning, wear protective gear such as goggles and gloves, as some agents may be harmful to the human body. If accidentally splashed onto clothing or skin, take appropriate measures immediately.

Table 9.Membrane fouling and corresponding types of maintenance chemical cleaning agents

Contamination type	Contaminants	Chemical cleaning formula
Inorganic	Calcium carbonate, iron salts and inorganic colloids	2% Citric acid, hydrochloric acid, or oxalic acid solution
	Barium sulfate, calcium sulfate and other insoluble inorganic salts	About 1% EDTA solution
Organic	Fat, humic acid, organic colloid, etc.	2% Sodium hydroxide solution
	Grease and other organic pollutants that are difficult to clean	2% Sodium hydroxide + 2% sodium hypochlorite solution
	Protein, starch, oil, polysaccharide, etc.	0.5%-1.5% Protease, amylase, etc.
Microorganism	Bacteria, viruses	2% Hydrogen peroxide or 2% sodium hypochlorite solution

7、FAQ

A、What are the important considerations when starting and shutting down the equipment?

Before starting the equipment, it is important to perform a safety check, pipeline check, and power supply check to ensure that everything is in order. Ensure that the outlet valve is open to prevent pressure buildup in the system. Prior to running the wastewater, it is necessary to run the acid circulation system.

When the equipment has been shut down for an extended period, it is essential to drain the wastewater and absorption liquid from the equipment and rinse it with clean water. The equipment valve should be switched to the emptying state.

B、What maintenance is required during long-term shutdown?

When the equipment is shoutdown, it must be flushed with clean water to prevent salt crystallization. Additionally, the system must be kept above 5°C to avoid freezing and damaging.

C、How can the fouling of the membrane caused by suspended matter be controlled?

Membrane fouling is a common issue in TMCS systems. Effective pretreatment processes, along with proper system operation and maintenance, are key to controlling fouling. The inlet water for the membrane contactor should undergo pre-filtration, such as ultrafiltration or multi-stage micron filtering, to eliminate insoluble particles. The minimum pre-filtration requirement is 10 microns absolute, with a 99.5% particle removal efficiency.

D、What causes scaling of membrane contactors, and how can it be prevented or cleaned?

Wastewater often contains high concentrations of calcium and magnesium ions, iron ions, or heavy metal ions that are prone to deposition, as well as colloidal organic matter that is easily condensed. This can lead to scaling of membrane components. Effective pretreatment is the primary method for preventing membrane scaling. However, if the system operates for an extended period, scaling becomes unavoidable. In such cases, appropriate cleaning can be done using high-concentration hydrochloric acid (e.g., 2%) or high-concentration alkali solution (e.g., 2% sodium hydroxide + 2% sodium hydroxide).

E、What factors will affect the service life of membrane contactors?

Large fluctuations in temperature over a short period of time will shorten the service life of the membrane contactor. Additionally, suspended solids, calcium and magnesium ions, and colloids in the water can easily cause membrane fouling and scaling, which will also affect the service life of the membrane contactor. Finally, too frequent cleaning and regeneration are also reasons for the shortened life of the membrane contactor.

F、What factors affect the concentration of absorption liquid?

Due to the process of membrane distillation, when removing ammonia, a small amount of water vapor enters the absorption liquid from the wastewater, causing the level of the absorption liquid to slowly rise.

The concentration of absorption liquid depends on the ammonia nitrogen concentration, temperature difference, salt concentration, etc.