SAMYANG

SAMYANG CORPORATION

TRILITE
삼양 트리라이트
Electrodeionizer

TRILITE EDI

ELECTRODEIONIZER - TECHNICAL DOCUMENT

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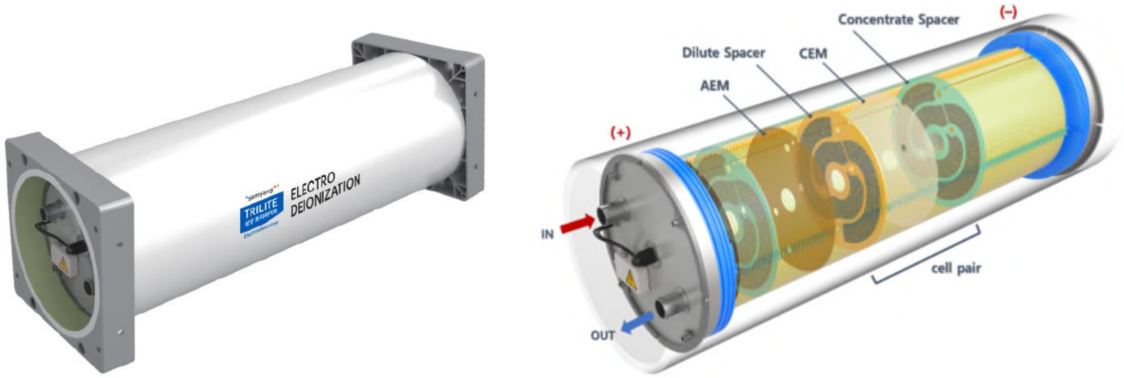
1. EDI PRINCIPLE

1.1 EDI Introduction

EDI is a continuous electro-deionization system that produces high-purity water using direct current electricity. The replacement and regeneration of ion exchange resin are not required, preventing the generation of regeneration waste, and allowing for the continuous production of ultrapure water without operational interruptions. Commonly known as CEDI or EDI, and produced and sold under the brand name "TRILITE EDI" by Samyang.

1.2 EDI Structure

EDI is comprised of components such as ion exchange membranes, ion exchange resin, and spacers. There are anode plate (+) and cathode plate (-) at both ends, and multiple cell pairs are stacked inside.



<Figure 1-1. External and Internal Structure of TRILITE EDI>

1) Ion Exchange Membrane

   It is created in the form of a membrane using synthetic polymer ion exchange resin. Ion exchange membranes are categorized into cation exchange membranes and anion exchange membranes depending on the production process. A cation exchange membrane (CEM) allows only cations to pass through, while an anion exchange membrane (AEM) allows only anions to pass through.

2) Ion Exchange Resin

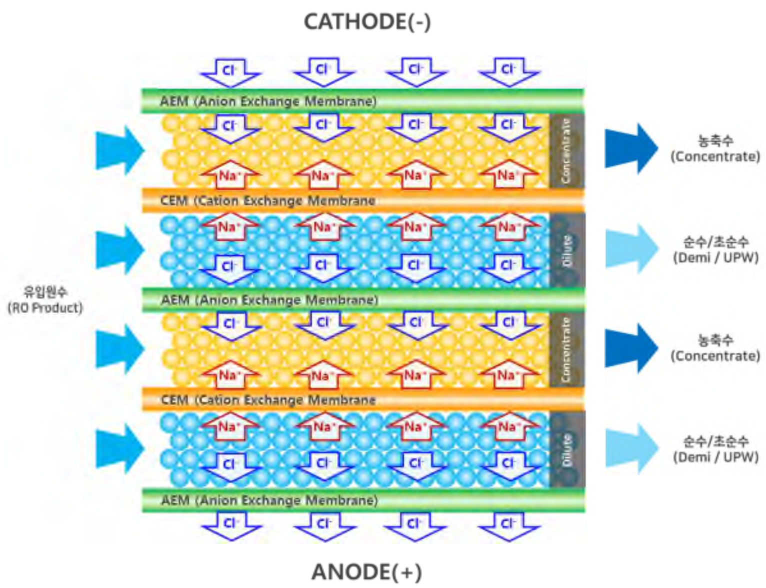
   It is a synthetic resin that plays a role in exchanging ions. Ion exchange resin increases the mobility of ions and, being a conductor, facilitates the smooth flow of electric current. This is directly related to the performance of EDI. Moreover, it is continuously regenerated through water splitting, enabling the continuous production of ultrapure water (Demi. water) without the need for separate processes.

3) Spacer

   A spacer is a 'space' where treated water and concentrate water are generated. The space where treated water is produced is referred to as the dilute spacer, while the space where concentrate water is generated is called the concentrate spacer. Each spacer is filled with ion exchange resin, and an ion exchange membrane is attached between the dilute spacer and the concentrate spacer. A single set consisting of these dilute and concentrate spacers is referred to as a cell pair. These cell pairs are then assembled and stacked to create what is known as a module.

1.3 EDI Operation Principle

Feed water is introduced into the spacer located between the membranes. Upon applying an electric current, electrostatic forces cause cations in the water to move toward the (-) electrode and anions to move toward the (+) electrode. During this process, the cations (Na^+, Ca^{2+}, etc.) present in the dilute spacer pass through the cation exchange membrane, while the anions (Cl^-, OH^-, etc.) pass through the anion exchange membrane and move to the concentrate spacer. This is similar to the principle of a traditional Electro-dialysis (ED/EDR) system. Water that has had ions removed as it passes through the dilute spacer becomes produced water (ultrapure and demi. water). On the other hand, the concentrate water discharged after passing through the concentrate spacer contains numerous ions and is either discharged or recirculated.



<Figure 1-2. Operation Principle of EDI>

1) FCE (Feed Conductivity Equivalent)

While the typical removal rate of salts by RO membranes is around 99%, dissolved carbon dioxide (CO_2) in water is hardly removed. When a high concentration of CO_2 is introduced into EDI, it acts as a load and causes the device's processing performance to deteriorate. Consequently, in EDI design, it is essential to consider CO_2 concentration.

FCE = Conductivity(㎲/㎝) + (CO_2 × 2.66)㎲/㎝ + (SiO_2 × 1.94)㎲/㎝

FCE (Feed Conductivity Equivalent) refers to electrical conductivity, which includes the concentration of dissolved CO_2 and dissolved SiO_2. It is obtained by converting the ppm concentrations into electrical conductivity (μS/cm). In this case, 1 ppm of CO_2 is equivalent to 2.66 μS/cm, and 1 ppm of SiO_2 is equivalent to 1.94 μS/cm. For example, if the conductivity measurement of RO-treated water is 2 μS/cm, with 1 ppm dissolved CO_2 and 0.1 ppm dissolved SiO_2, the FCE is calculated as 2 μS/cm + (1 × 2.66 μS/cm) + (0.1 × 1.94 μS/cm) = 4.85 μS/cm.

2) Regeneration of ion exchange resin

The application of direct current electricity initiates water splitting within the ion exchange resin in the ion exchange membrane and spacer, disintegrating H_2O into H^+ and OH^-. H^+ and OH^- ions regenerate the cation and anion exchange resins within the dilute spacer through the following reaction equation.

The electro-regeneration reaction occurs continuously without the need for separate regeneration processes, allowing for continuous operation without the generation of waste solution. Regenerated ion exchange resin increases the desalination (ion removal) rate and efficiently removes weakly ionized compounds (CO_3^{2-}, SiO_2, etc.).

Cation Exchange Resin Regeneration Reaction Equation	Anion Exchange Resin Regeneration Reaction Equation
$R\text{-}Na^+ + H^+ \rightarrow R\text{-}H^+ + Na^+$	$R\text{-}Cl^- + OH^- \rightarrow R\text{-}OH^- + Cl^-$

3) Removal of weakly ionized compounds

Weakly ionized compounds such as CO_2, Silica, and Boron are removed as follows. The weakly ionized compounds in the dilute spacer combine with ions (H^+, OH^-) generated by water splitting, acquiring an electric charge. The cations are attracted to the cathode and pass through the cation exchange membrane, while the anions are attracted to the anode and pass through the anion exchange membrane and are removed to the concentrate spacer.

① $CO_2 + OH^- \rightarrow HCO_3^-$

② $HCO_3^- + OH^- \rightarrow CO_3^{2-} + H_2O$

③ $SiO_2 + OH^- \rightarrow HSiO_3^-$

④ $H_3BO_3 + OH^- \rightarrow B(OH)_4^-$

⑤ $NH_3 + H^+ \rightarrow NH_4^+$

1.4 EDI Advantages

Conventional ultrapure water production facilities and condensate polishing systems in nuclear power plants, thermal power plants, semiconductor manufacturing processes, etc., chemically regenerate ion exchange resins for their reuse. In this process, various issues arise, including the generation of a significant amount of chemical waste. This technology resolves these numerous drawbacks by utilizing only direct current electricity without the need for chemical usage.

1) Throughout the process, no chemical waste is generated, making it eco-friendly and eliminating the need for separate wastewater treatment facilities.
2) In conventional ultrapure water facilities, during the regeneration of ion exchange resins, it is not possible to produce treated water. Therefore, to ensure continuous production, a

separate standby facility is required. However, EDI produces demi. water continuously without the need for operation shutdowns, as it utilizes only direct current electricity without chemical regeneration.

3) As it does not involve any handling of chemicals (strong acids, strong alkalis), it prevents safety accidents and enhances the durability of high-value production equipment by eliminating any concerns of corrosion to surrounding key devices.
4) There is no auxiliary equipment required for chemical regeneration (such as chemical storage tanks, chemical injection pumps, neutralization tanks, etc.), making the equipment cost-effective and allowing for a small installation area.
5) Since it utilizes direct current electricity and ion exchange membranes, the operation is simple and maintenance is straightforward.

2. TRILITE EDI PRODUCT INTRODUCTION

2.1 TRILITE EDI Type & Characteristics

<Figure 2.1 Small Capacity EDI (TNS & TUS Series)>

<Figure 2.2 Large Capacity EDI (TN & TU Series)>

Type	Specification
TN Series & TU Series	① Round Disk Plate Type ② Capable for Large Capacity (10m³/hr↑) ③ Easy to design skid, Simple Facilities ④ A wide range of flow rate ⑤ Long flow path, stable performance (Tornado Flow Design) ⑥ High Operating Pressure (Max. 10bar) ⑥ For Demi. Water → TN Series (TN-10, TN-12, TN-15) ⑦ For UPW → TU Series (TU-04, TU-10, TU-14)
TNS Series & TUS Series	① Rectangular Plate and Frame Type ② Capable for Small Capacity (8m³/hr↓) ③ Compact Structure, Easy to handle and install ④ A variety of product models can be selected. ⑤ For Demi. Water → TNS Series (TNS-03, TNS-04, TNS-05, TNS-06, TNS-07) ⑥ For UPW → TUS Series (TUS-01, TUS-02, TUS-03, TUS-04, TUS-05)

2.2 TRILITE EDI Product Line-Up & Specification

1) TN Series

MODEL	TN-10	TN-12	TN-15
Maximum Feed Water Specification			
FCE*	< 40㎲/㎝ (CO_2 < 5 ppm, Silica < 0.5 ppm)		
Inlet Pressure	Max. 10.0kgf/㎠		
Inlet Temp. / pH	5~45℃ (Nor. 25℃) / 4 ~ 11		
Typical Module Performance			
Recovery	90 ~ 95%		
Capacity	10~12㎥/hr	12~15㎥/hr	Max. 25㎥/hr
Pressure Drop	< 2.5kgf/㎠		
DC Vol. / Amp.	0~600V / 0~6A		
Product Resistivity	> 16.0㏁·㎝		
Silica / Boron Removal	≥ 95%		
Sodium / Chloride Removal	≥ 99.8%		
Physical Specifications			
Size (mmID x mmL)	470 × 1,964	470 × 2,110	470 × 2,310
Weight	Empty : 430kg / Oper. : 530kg	Empty : 450kg / Oper. : 590kg	Empty : 470kg / Oper. : 650kg
Material	Body : Glass Reinforced Plastic (GRP)		

* FCE : Feed Water Conductivity Equivalent including CO_2 and Silica

2) TU Series

MODEL	TU-04	TU-10	TU-14
Maximum Feed Water Specification			
FCE*	< 10㎲/㎝ (CO_2 < 1.25 ppm, Silica < 0.2 ppm)		
Inlet Pressure	Max. 10.0kgf/㎠		
Inlet Temp. / pH	20~45℃ (Nor. 25℃) / 4 ~ 11		
Typical Module Performance			
Recovery	≥ 95%		
Capacity	4~6㎥/hr	10~13㎥/hr	14~16㎥/hr
Pressure Drop	< 2.5kgf/㎠		
DC Vol. / Amp.	0~500V / 0~6A		
Product Resistivity	> 17.5㏁·㎝ (< 5㎲/㎝ : 2-Pass RO), > 18.0㏁·㎝ (< 1㎲/㎝ : DW)		
Silica / Boron Removal	≥ 99.0%		
Sodium / Chloride Removal	≥ 99.9%		
Physical Specifications			
Size (mmID x mmL)	470 × 1,095	470 × 2,110	470 × 2,510
Weight	Empty : 180kg / Oper. : 250kg	Empty : 360kg / Oper. : 500kg	Empty : 380kg / Oper. : 560kg
Material	Body : Glass Reinforced Plastic (GRP)		

3) TNS Series

MODEL	TNS-03	TNS-04	TNS-05	TNS-06	TNS-07
Maximum Feed Water Specification					
FCE*	< 40㎲/㎝ (CO_2 < 5 ppm, Silica < 0.5 ppm)				
Inlet Pressure	Max. 7.0kgf/㎠				
Inlet Temp. / pH	5~45℃ (Nor. 25℃) / 4 ~ 11				
Typical Module Performance					
Recovery	90 ~ 95%				
Capacity (Nor. Flow rate)	1.5~3.3m³/hr (3.0m³/hr)	2.0~4.4m³/hr (4.0m³/hr)	2.5~5.5m³/hr (5.0m³/hr)	3.0~6.6m³/hr (6.0m³/hr)	3.5~8.0m³/hr (7.0m³/hr)
Pressure Drop	< 3.0kgf/㎠				
DC Vol. / Amp.	0~500V / 0~6A				
Product Resistivity	> 16.0MΩ·㎝				
Silica / Boron Removal	≥ 98.0% / ≥ 95.0%				
Sodium / Chloride Removal	≥ 99.0%				
Physical Specifications					
Size (mmL x mmW x mmH)	570x315x608	730x315x608	810x315x608	865x315x608	915x315x608
Weight (Oper.)	90 kg	121 kg	136 kg	147 kg	156kg
Material	Dilute & Concentrate Chamber : CPVC Anode / Cathode Electrode : Titanium plated Platinum / SS316L				

4) TUS Series

MODEL	TUS-01	TUS-02	TUS-03	TUS-04	TUS-05
Maximum Feed Water Specification					
FCE*	< 10㎲/㎝ (CO_2 < 1.25 ppm, Silica < 0.2 ppm)				
Inlet Pressure	Max. 7.0kgf/㎠				
Inlet Temp. / pH	20~45℃ (Nor. 25℃) / 4 ~ 11				
Typical Module Performance					
Recovery	≥ 95%				
Capacity (Nor. Flow rate)	0.4~1.2m³/hr (1.0m³/hr)	1.2~2.2m³/hr (2.0m³/hr)	1.6~3.3m³/hr (3.0m³/hr)	2.0~4.4m³/hr (4.0m³/hr)	2.4~5.5m³/hr (5.0m³/hr)
Pressure Drop	< 3.0kgf/㎠				
DC Vol. / Amp.	0~500V / 0~6A				
Product Resistivity	> 17.0MΩ·㎝				
Silica / Boron Removal	≥ 99.0% / ≥ 98.0%				
Sodium / Chloride Removal	≥ 99.9%				
Physical Specifications					
Size (mmL x mmW x mmH)	363x315x608	497x315x608	630x315x608	710x315x608	830x315x608
Weight (Oper.)	52 kg	78 kg	104 kg	119 kg	142kg
Material	Dilute & Concentrate Chamber : CPVC Anode / Cathode Electrode : Titanium plated Platinum / SS316L				

3. EDI INSTALLATION / REPLACEMENT

3.1 EDI Installation & Replacement Guideline & Cautions

EDI installation involves significant lifting work, so attention should be given to safety during disassembly and assembly processes. And when transporting EDI products, always handle with caution to prevent damage.

1) Disassembly and Transportation

① Disassemble the existing product's connecting pipes to separate them from the skid.

② Transfer the module, which is packaged in a box or packaging material, to the installation site.

③ After unpacking, inspect the condition of the module and verify its components. All new EDI systems undergo performance testing, and after completion, they are packaged while filled with demi. water to prevent drying inside the EDI. When storing the EDI, if the plugs are removed, the sealed demi. water inside may leak out, causing the ion exchange resin and membrane within the module to dry out, resulting in critical damage to the EDI. Therefore, ensure that the plugs attached to each nozzle of the EDI are securely connected and sealed.

④ Safely move the EDI onto the skid using transportation equipment (such as forklifts or cranes).

2) Piping Connection

① Thoroughly clean the pre-treatment equipment and related piping with clean water that has been treated by RO or is free from particles. This procedure must be carried out before supplying feed water to the EDI module. If any residual substances from the EDI pre-treatment equipment and associated piping, such as PVC and SUS welding residues, particles, etc., are introduced to the EDI module, it could result in severe damage.

② Establish connections between all interface points of the EDI to the system (piping). The nozzle specifications for each product are as follows.

Nozzle Specification				
Model	Description	Size(A)	Material	Rating
TN & TU Series	Feed Water Inlet	50	STS316	Grooved Joint
	Product Outlet	50	STS316	Grooved Joint
	Concentrate Inlet	25	STS316	Grooved Joint
	Concentrate Outlet	25	STS316	Grooved Joint
	Electrode Water Inlet	NPT 1/4"	STS316	Female SCR'D
	Vent & Electrode Water Inlet	NPT 1/4"	STS316	Female SCR'D
TNS & TUS Series	Feed Water Inlet	25	PP	Male SCR'D
	Product Outlet	25	PP	Male SCR'D
	Concentrate Inlet	20	PP	Male SCR'D
	Concentrate Outlet	20	PP	Male SCR'D
	Electrode Water Outlet	12mm	PP	Hose

③ Inspect the leakage condition of the electrode water, feed water, concentrate water, and produced water piping.

3) Electrical Connection

① Connect the anode (+) and cathode (-) electrical wires. Before applying DC power, it is essential to ensure that all electrical wires are correctly connected. Operating in a state where the anode (+) and cathode (-) directions are reversed can deteriorate the treated water quality and cause damage to the electrode plates. In the electrical cable, the red wire indicates the anode (+), and the blue wire indicates the cathode (-).

② Ground the EDI module itself by connecting it to the grounding wire. Grounding is crucial in EDI installation. To ensure effective grounding, it's imperative to connect the grounding wire to the EDI module, rectifier, and skid components. If the EDI is not grounded and some of the current supplied to the EDI escapes through the grounding wire, it can affect the performance and pose a risk of electric shock in the event of abnormal currents.

3.2 EDI Replacement Lifespan

1) Replacement Lifespan Condition

EDI is composed of ion exchange resin and ion exchange membranes. Since the ion exchange membrane is also made using ion exchange resin as a material, the replacement lifespan of EDI can be estimated based on the ion exchange resin.

Strong anion exchange resin replacement is recommended when the strong anion capacity falls below 75% of the total capacity, as specified by the resin manufacturer. However, in typical industrial ultrapure treatment systems, replacement is recommended when the total capacity drops below 70%. While there can be significant variations based on operational conditions, in ion exchange systems operating under normal conditions, replacement is usually needed after approximately 4 years when the total capacity falls below 70%.

2) Calculation of Replacement Lifespan

The formula for calculating the replacement lifespan of EDI is as follows, and replacement is estimated as a criterion when the capacity loss exceeds 30% (below 70% of the total capacity).

Capacity Loss = (6%/year[1] x Ⓐ) + (0.2%/cycle[2] x Ⓑ) + (2%/year[3] x Ⓐ)

* Ⓐ: Years of use Ⓑ: Number of chemical cleaning cycles

[1] Ion exchange resin Capacity loss : Every year 6%

[2] Ion exchange resin and ion exchange membrane degradation due to chemical cleaning : 0.2% loss per cleaning cycle

[3] Ion exchange resin and ion exchange membrane degradation due to fouling, oxidation : Every year 2%

For example, if the EDI has been in use for 4 years and chemical cleaning occurs 1~2 times during normal operation over the 4 years, assuming chemical cleaning happens 2 times, the capacity loss can be calculated as follows. With a capacity loss exceeding 30%, the estimated replacement cycle is 4 years.

Capacity loss = (6%/year x 4 years) + (0.2%/cycle x 2 times) + (2%/year x 4 years) = 32.4%

3) Lifespan of a Normally Operating EDI : 3 ~ 5 years

The normal operational lifespan of an EDI system is between 3 to 5 years, which can vary based on the feed water quality. It is important to pay attention to feed water quality and equipment management to minimize the capacity loss.

4. EDI SYSTEM OPERATING & MAINTENANACE

4.1 Preparation for Operation

Before beginning the operation, the quality of the feed water should be regularly checked to ensure the following conditions are met:

The feed water conditions may vary depending on the site conditions and the produced water guarantee levels

Model	TN & TNS Series	TU & TUS Series
Temperature	5 ~ 45 ℃	20 ~ 45 ℃
pH	4 ~ 11	
Conductivity, FCE	< 40 ㎲/㎝ (CO_2 < 5ppm, Silica < 0.5 ppm)	< 10 ㎲/㎝ (2-Pass RO Permeate) (CO_2 < 1.25ppm, Silica < 0.2 ppm)
Fe, Mn, H_2S	< 0.01 ppm	
TOC	< 0.5 ppm	
Total Hardness	< 1.0 ppm as $CaCO_3$ (at Recovery 90%)	< 0.1 ppm as $CaCO_3$ (at Recovery 95%)
Free Chlorine	< 0.05 ppm	< 0.01 ppm

4.2 Operation

It consists of two stages: The Make-up process and the Service process (Normal operation), and the details are as follows.

1) Make-Up

This process involves filling the dilute spacer and concentrate spacer within the module with feed water (R/O treated water) using the EDI feed pump. The water filled in the dilute spacer is discharged through the produced water piping, while the water filled in the concentrate spacer is discharged through the concentrate water outlet and electrode water outlet piping.

Check if the specified flow rate is being properly discharged from the outlet piping of produced water, concentrate water, and electrode water.

The water used in the Make-up process is recycled for reuse. The water discharged through the produced water outlet piping is directed to the EDI feed tank, while the water discharged from the concentrate water outlet and electrode water piping is sent to the inlet-side of the R/O.

2) Service (Normal Operation)

① Supply of Direct Current Power within the Stack

Direct current power within the stack is supplied through the operation of the rectifier. Be cautious when the rectifier is activated while the feed water and produced water valves are closed or while the supply of feed water to the EDI stack is interrupted due to the trip of the EDI feed pump. In such conditions, critical damage to the electrode plates within the EDI can occur.

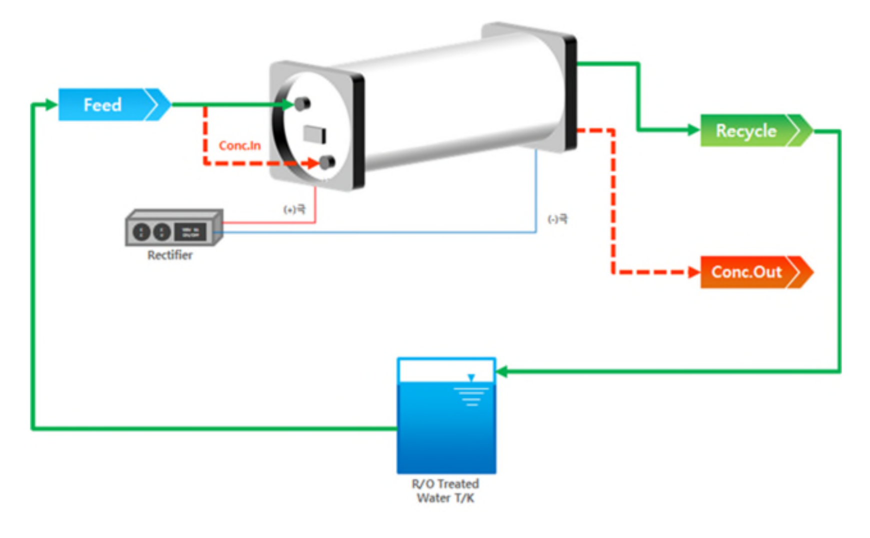
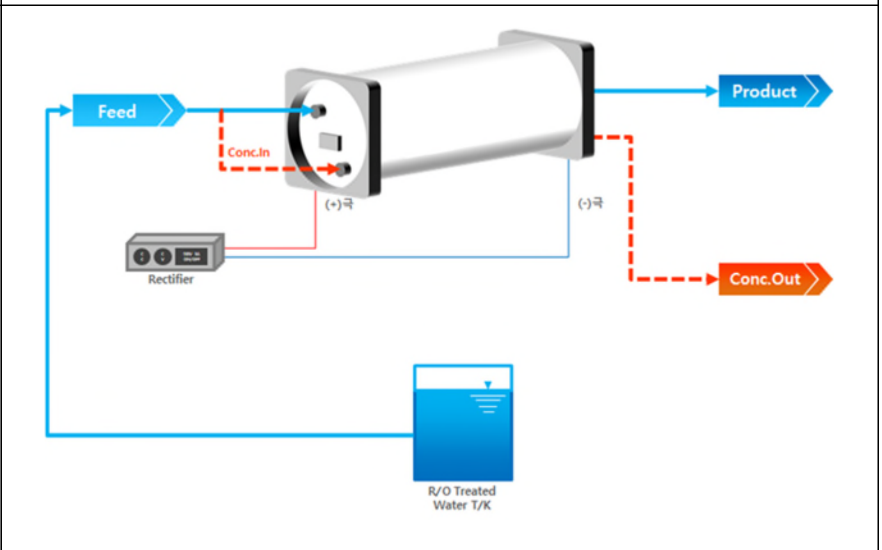
② Current and Voltage Adjustment

Depending on the quality of feed water and desired water, the current is adjusted to an appropriate level to achieve economical operation. In most cases, the operation is carried out using either constant-voltage or constant-current mode. During constant-voltage operation, the voltage remains constant while the current automatically adjusts depending on the EDI stack load (feed water quality, temperature, treated water flow rate). On the other hand, during constant-current operation, the current remains constant while the voltage automatically adjusts depending on the EDI stack load. Typically, the operating current is maintained at 0.3 to 4A per stack, and voltage and current limits are set to prevent abrupt increases in operating voltage.

Low operating current reduces ion exchange performance and increases internal resistance inside the module. In the case of the TNS & TUS series, it is not recommended to operate less than 1.5A. At the initial setting, the current of 2A is applied to check the product water quality, and is adjusted within 2~4A.

Adjustment of concentrate water discharge flow rate and pressure.

Adjust the discharge flow rate and discharge pressure of the concentrate water by adjusting the Make-up flow control valve for the concentrate chamber and the discharge flow control valve for the concentrate water. To minimize concentrate spacer contamination, the discharge flow rate of concentrate water is set to about 10% of the feed water. If the pressure in the concentrate spacer is high, there is a risk of concentrate water flowing into the dilute spacer, leading to contamination of the treated water quality. Therefore, the pressure in the dilute spacer (Product) must be maintained at 1.0~1.5kgf/cm² higher than the outlet pressure of the concentrate spacer (Conc. Out) to prevent such contamination. In the case of TNS & TUS series products operating in Count-Current method, concentrate in & out pressure is adjusted to be lower than product out pressure at least 0.02Mpa (0.2kgf/cm^2)

Make-Up	
Service	

<Figure 4-1. EDI Service Process>

4.3 Rectifier Specification

1) What is rectifier?

A rectifier refers to an electrical circuit element or device designed with a focus on rectification to convert alternating current (AC) power into direct current (DC) power. In the water treatment industry, the three-phase full-wave rectification method is primarily employed. In addition, it is used to convert, input, and control electricity (power) entering the water treatment facility into a certain amount of voltage/current that is compatible with the EDI module.

2) Rectifier specification

The rectifier used for TN & TU Series EDI is typically a rack-type rectifier that converts 3-phase 460V AC power using Silicon Thyristors to control the phase and provide DC power. It is capable of operating in both constant voltage and constant current modes. While in operation, it is designed with a limit operation method (Current limit, Voltage limit) to provide a more stable and efficient power supply.

① TN & TU Series Power Requirements

ITEM			SPECIFICATION
SYSTEM		Service Rating	- DC 500V, 5A - DC 600V, 10A
		Rectification Method	3PHASE Full-wave Rectification (SCR Phase Control)
		Control System	CV/CC Operation
		Cooling System	Forced Air Cooled
Electrical Characteristic	Input (AC)	Rated Input Voltage, Phase	AC 460V, 3PHASE
		Line Regulation	±10%
		Rated Frequency	60Hz
		Power Factor	≥ 85%
	Output (DC)	Max. Compliance Voltage	DC 600 Voltage
		Max. Output Current	10 Ampere
		Voltage/Current Stability	± 3%
		Opearting Voltage Range	100 ~ 600V
		Operating Current Range	1 ~ 10A
		Efficiency	≥ 88%
		Ripple Factor	< 2%

② TNS Series Maximum Power Requirements

Model	TNS-03	TNS-04	TNS-05	TNS-06	TNS-07
Input Voltage	300V	400V	500V		
Input Current	6.0A				
Max. Input Power	1.8kW	2.4kW	3.0kW		
Frequency	50Hz				

③ TUS Series Maximum Power Requirements

Model	TUS-01	TUS-02	TUS-03	TUS-04	TUS-05
Input Voltage	100V	200V	300V	500V	
Input Current	3.0A	4.0A	6.0A		
Max. Input Power	0.3kW	0.8kW	1.8kW	3.0kW	
Frequency	50Hz				

4.4 Chemical Cleaning (CIP) and Disinfection

During prolonged operation of EDI under normal conditions, the EDI stack can become contaminated by colloidal suspended solids (Colloid, Clay, Silt, etc.), organic or inorganic particulates, microbials, and inorganic compounds such as Silica, CaCO3, CaSO4, and metal hydroxides that remain in the feed water. Also, periodically removing these contaminants through a cleaning process is called CIP (Cleaning In Place).

If contamination occurs within the EDI stack, it can lead to reduced treated water quantity, lower salt permeability, degradation in treated water quality, and increased differential pressure within the EDI module. Additionally, if the cleaning process is delayed and the system operates for an extended period, the efficiency of contaminant removal through cleaning decreases. Hence, timely cleaning is crucial. Moreover, if performance recovery is insufficient after cleaning, proactive actions like analyzing contaminants and then pursuing steps such as choosing suitable chemicals and adjusting the cleaning frequency should be taken. If scheduled chemical cleaning is delayed, severe contamination that is difficult to recover even through chemical cleaning can occur in the EDI system. Therefore, chemical cleaning should be performed as early as possible in the event of initial contamination.

1) Importance of Chemical Cleaning (CIP)

For long-term usage, it is recommended to perform chemical cleaning periodically even if there is no special problem during operation. If there are below circumstances, immediate chemical cleaning (CIP) should be performed.

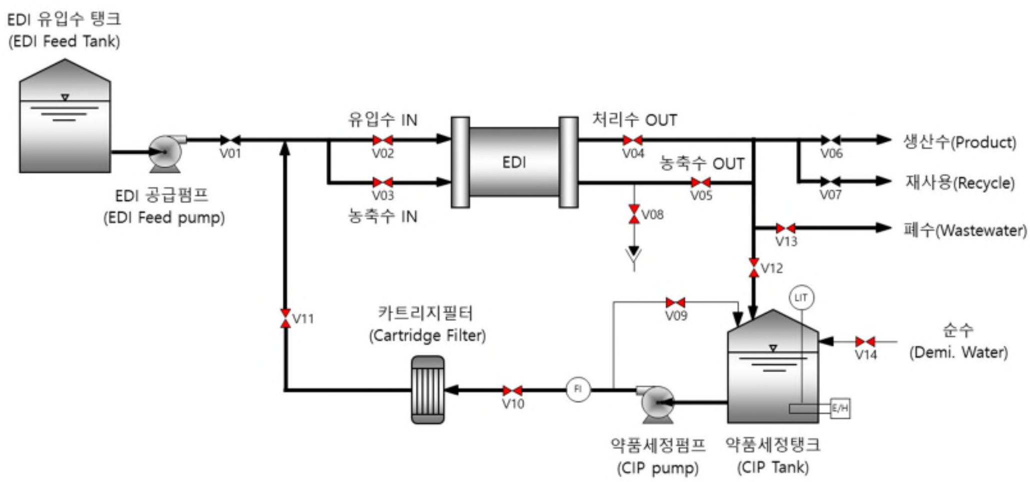
① When the treated water quantity decreases by more than 10% (without changes in temperature and pressure)

② When the treated water conductivity decreases by more than 10% (without changes in temperature, feed water quality, and pressure)

③ When the pressure difference between produced water and concentrate water increases by about 15% (without changes in temperature and pressure)

④ When the operating current decreases by more than 20 to 25% (without changes in feed water quality, treated water flow rate, temperature, and pressure)

⑤ When the electrode water flow rate decreases by more than 20 to 25% (without changes in feed water quality, treated water flow rate, temperature, and pressure)



<Figure 4-2. Chemical Cleaning (CIP) PFD>

2) Chemical cleaning (CIP) procedure

① Before performing EDI chemical cleaning, be sure to replace the used cleaning cartridge filter with a new one. Using a contaminated cleaning cartridge filter can lead to severe contamination during the EDI chemical cleaning process.

② Fill the cleaning tank with EDI produced water and verify the agitator and temperature settings before dissolving chemicals according to the intention of the cleaning process.

③ Mix and circulate the cleaning solution using the agitator and cleaning pump, adjusting the pH. All cleaning processes are performed manually.

④ Depending on the source of contamination, choose the type of cleaning. If the source of contamination is complex or unclear, conduct inorganic cleaning first, followed by organic cleaning.

⑤ Depending on the level of contamination, cleaning of the dilute chamber and concentrate chamber can be conducted together. Generally, conducting separate cleaning for the dilute chamber and concentrate chamber is more effective. In this case, perform dilute chamber cleaning first, followed by concentrate chamber cleaning. During cleaning, the cleaning pressure is maintained below 3 kgf/cm^2.

⑥ In the event of chemicals splashing or spilling onto the body, immediately rinse the affected area with a large volume of flowing water for at least 15 minutes. Respond as quickly as possible and seek immediate medical attention after completing emergency measures for treatment and prescription.

3) Common types of contaminants and removal methods

Alkaline cleaning agents are used to remove contamination caused by microbials, organic substances, and silica, while acidic cleaning agents are used to remove contamination caused by inorganic substances such as iron and hardness scale.

① 2.5% HCl Cleaning

Cleaning to remove contamination from Ca^{2+}, Mg^{2+} scale, and metal oxides occurs mainly in the concentrate chamber. If the effects of cleaning are not satisfactory, repeat cleaning or gradually increase the concentration of HCl to a range of 2.5~3.0% for effective cleaning.

Chemical input amount for acid cleaning (per unit)

Chemical	Input Amount
99% NaCl	30.0kg
35% HCl	37.0L
Demi. Water	$0.6m^3$

HCl Cleaning Procedure

[Step 1] Start Flushing
To rinse out the contaminants present in the stack, pipelines, and cleaning tank before chemical cleaning, a flushing process with demi water is conducted at a

rate of about 14㎥/hr for approximately 2 to 5 minutes.

- Open V/V : V02, V03, V04, V05, V10, V11, V13, V14
- Pump : CIP Pump

[Step 2] Dilute Chamber HCl Recycle

Add 2.5% HCl (0.6㎥ pure water, 37ℓ of 35% HCl) to the cleaning tank and dissolve it.

- Open V/V : V09
- Pump : CIP Pump
- Electric Heater & Agitator Run

Open the cleaning line valve of the dilution chamber. Circulate the dilution chamber through the cleaning tank for 1 hour using the cleaning process of Ca^{2+}, Mg^{2+} and hardness scale. Adjust the chemical inflow rate to approximately 12㎥/hr.

Maintain the pH value at approximately 0.5 to 1.0 during the cleaning process. If the pH value rises above 1.0 during the circulation process, add HCl solution to adjust it back to the range of 0.5 to 1.0.

- Open V/V : V02, V04, V10, V11, V12
- Pump : CIP Pump
- Electric Heater Run

[Step 3] Concentrate Chamber HCl Recycle

After the dilute chamber HCl recycle process is completed, close the valve on the dilute chamber side and open the valve on the concentrate chamber cleaning line. Contaminated stacks are cleaned using the cleaning process of Ca, Mg, and hardness scale, circulating the concentrate chamber through the cleaning tank for 1 hour. Adjust the chemical inflow rate to approximately 2㎥/hr.

Maintain the pH value at approximately 0.5 to 1.0 during the cleaning process. If the pH value rises above 1.0 during the circulation process, add HCl solution to adjust it back to the range of 0.5 to 1.0.

- Open V/V : V03, V05, V10, V11, V12
- Pump : CIP Pump
- Electric Heater Run

[Step 4] Soaking (Optional)

In cases of severe EDI contamination, this procedure is carried out where the cleaning agent is filled in the stack. Inlet and outlet valves are closed, and the process is conducted for 1 hour. If the cleaning is not effective, the procedure can be extended for a longer period.

[Step 5] CIP Tank Drain & Water Flushing

After fully draining the cleaning solution in the cleaning tank, the remaining cleaning solution in the stack, pipes, and cleaning tank is removed by flushing with demi. water and discharging to the trench drains for about 14 to 20 minutes.

- Open V/V : V02, V03, V04, V05, V10, V11, V13
- Pump : CIP Pump

[Step 6] Salt Flushing
Add 5% NaCl (Demi. Water : 0.6 m³, 99% NaCl : 30 kg) to the cleaning tank, and start the agitator to ensure complete dissolution of NaCl. Return the 5% NaCl solution to the cleaning tank via the cleaning pump while the agitator is in operation. To convert the ion exchange resin filled in the cell to R-Na and R-Cl forms, the process is carried out by discharging a salt solution for about 3 minutes or more to the trench drains. The inflow rate is adjusted to be at least 3 minutes by manipulating the cleaning inlet valve at a rate of approximately 12 m³/hr. - Open V/V : V02, V03, V04, V05, V10, V11, V13, V14 - Pump : CIP Pump
[Step 7] Final Water Flushing
To rinse out any remaining salt and cleaning solution in the stack, pipes, and cleaning tank, perform a flushing process using demi. water for approximately 1 hour until the pH becomes neutral. Adjust the inflow rate to approximately 14㎥/hr. - Open V/V : V02, V03, V04, V05, V10, V11, V13, V14 - Pump : CIP Pump
[Step 8] Blow-down & Service
After opening or closing all valves in the operational state, operate the EDI while circulating the treated water to the filtered water reservoir under the designed flow rates and pressure conditions until the desired treated water quality is achieved (Blow-down). Once the desired treated water quality is attained, conduct the service process to the demi.water tank. The duration of the blow-down takes at least 6 hours or more, depending on the residual amount of chemicals and the degree of regeneration after the final flushing. - Open V/V : V01, V02, V03, V04, V05, V07, V08 [Blow-down] - Open V/V : V01, V02, V03, V04, V05, V06, V08 [Service] - Pump : EDI Feed Pump - Rectifier Run

② 5% Brine & 1% NaOH Cleaning

This cleaning is carried out to remove typical organic and silica contaminants. Organic contaminants are commonly found in the dilute chamber, while silica is commonly found in the concentrate chamber.

Chemical input amount for brine & NaOH cleaning (per unit)

Chemical	Input Amount
99% NaCl	30.0kg
45% NaOH	9.0L

Chemical	Input Amount
Demi. Water	0.6m^3

Brine & NaOH Cleaning Procedure

[Step 1] Start Flushing
To rinse out the contaminants present in the stack, pipelines, and cleaning tank before chemical cleaning, a flushing process with demi water is conducted at a rate of about 14㎥/hr for approximately 2 to 5 minutes. - Open V/V : V02, V03, V04, V05, V10, V11, V13, V14 - Pump : CIP Pump
[Step 2] Dilute Chamber Brine & NaOH Recycle
Add 5% NaCl (Demi. Water : 0.6 m³, 99% NaCl : 30 kg) to the cleaning tank, and start the agitator to ensure complete dissolution of NaCl. Return the 5% NaCl solution to the cleaning tank via the cleaning pump while the agitator is in operation. - Open V/V : V09 - Pump : CIP Pump - Electric Heater & Agitator Run Add 1% NaOH to the dissolved 5% NaCl solution and mix until fully dissolved. Open the cleaning line valve of the dilution chamber. Contaminated stacks are cleaned using the cleaning process of organic and silica, circulating the dilution chamber through the cleaning tank for 1 hour. Adjust the chemical inflow rate to approximately 12㎥/hr. Maintain the pH value at approximately 11 to 12. In the case of heavy contamination, perform the cleaning at around 35°C. - Open V/V : V02, V04, V10, V11, V12 - Pump : CIP Pump - Electric Heater Run
[Step 3] Concentrate Chamber Brine & NaOH Recycle
After the brine & NaOH recycle process of the concentrate chamber is completed, close the valve on the dilute chamber side and open the valve on the concentrate chamber cleaning line. Contaminated stacks are cleaned using the cleaning process of organic and silica, circulating the concentrate chamber through the cleaning tank for 1 hour. Adjust the chemical inflow rate to approximately 2㎥/hr. Maintain the pH value at approximately 11 to 12. In the case of heavy contamination, perform the cleaning at around 35°C. - Open V/V : V03, V05, V10, V11, V12 - Pump : CIP Pump - Electric Heater Run

[Step 4] Soaking (Optional)
In cases of severe EDI contamination, this procedure is carried out where the cleaning agent is filled in the stack. Inlet and outlet valves are closed, and the process is conducted for 1 hour. If the cleaning is not effective, the procedure can be extended for a longer period.
[Step 5] CIP Tank Drain & Water Flushing
After fully draining the cleaning solution in the cleaning tank, the remaining cleaning solution in the stack, pipes, and cleaning tank is removed by flushing with demi. water and discharge to the trench drain for approximately 1 hour until the pH becomes neutral. Adjust the inflow rate to approximately 14㎥/hr using the cleaning inlet valve. - Open V/V : V02, V03, V04, V05, V10, V11, V13 - Pump : CIP Pump
[Step 6] Blow-down & Service
After opening or closing all valves in the operational state, operate the EDI while circulating the treated water to the filtered water reservoir under the designed flow rates and pressure conditions until the desired treated water quality is achieved (Blow-down). Once the desired treated water quality is attained, conduct the service process to the demi.water tank. The duration of the blow-down takes at least 6 hours or more, depending on the residual amount of chemicals and the degree of regeneration after the final flushing. - Open V/V : V01, V02, V03, V04, V05, V07, V08 [Blow-down] - Open V/V : V01, V02, V03, V04, V05, V06, V08 [Service] - Pump : EDI Feed Pump - Rectifier Run

4) Input amount of chemical for TNS & TUS Series

TNS & TUS Series are proceeded with same CIP procedure as above. Depends on the module capacity, it is necessary to adjust the amount of chemical and flow rate.

① Chemical (2% HCl) input amount for acid cleaning (per unit)

Chemical	TNS-03	TNS-04	TNS-05	TNS-06	TNS-07
Demi. Water	27.74GPM (105L)	36.98GPM (140L)	41.61GPM (157.5L)	41.61GPM (157.5L)	46.23GPM (175L)
36.5% HCl	1.5GPM (5.75L)	2.0GPM (7.67L)	2.25GPM (8.63L)	2.25GPM (8.63L)	2.5GPM (9.58L)

Chemical	TUS-01	TUS-02	TUS-03	TUS-04	TUS-05
Demi. Water	9.24GPM (35L)	18.49GPM (70L)	27.74GPM (105L)	36.98GPM (140L)	41.61GPM (157.5L)
36.5% HCl	0.5GPM (1.892L)	1.0GPM (3.785L)	1.5GPM (5.75L)	2.0GPM (7.67L)	2.25GPM (8.63L)

② Chemical (5% Brine & 1% NaOH) input amount for brine & NaOH cleaning (per unit)

Chemical	TNS-03	TNS-04	TNS-05	TNS-06	TNS-07
Demi. Water	27.74GPM (105L)	36.98GPM (140L)	41.61GPM (157.5L)	41.61GPM (157.5L)	46.23GPM (175L)
99.9% NaCl	5.25kg	7.0kg	7.875kg	7.875kg	8.75kg
50.0% NaOH	1.05kg	1.4kg	1.575kg	1.575kg	1.75kg

Chemical	TUS-01	TUS-02	TUS-03	TUS-04	TUS-05
Demi. Water	9.24GPM (35L)	18.49GPM (70L)	27.74GPM (105L)	36.98GPM (140L)	41.61GPM (157.5L)
99.9% NaCl	1.75kg	3.5kg	5.25kg	7.0kg	7.875kg
50.0% NaOH	0.35kg	0.70kg	1.05kg	1.4kg	1.575kg

5. EDI HANDLING & STORAGE PRECAUTIONS

5.1 Storage Precautions

1) Storage Standards

EDI should be protected to prevent bacterial reproduction or performance degradation during long-term storage, shipping, and shutdown periods. The storage standards are as follows.

Storage Period	Storage Temperature
6 months	Ambient (5~30℃)

2) Storage Precautions

① Maintaining appropriate temperature

All new EDI systems undergo performance testing, and after completion, they are filled with demi. water and sealed. Bacteria reproduce rapidly at temperatures of 25~35℃ in ultrapure water, while their reproduction slows down at temperatures below 15~18℃. Therefore, it is advisable to store it at lower temperatures under air conditioner conditions.

However, excessively low temperatures should be approached with caution. When EDI is frozen, irreparable damage can occur to the membranes or the module exterior can crack, so it is important to store inside a building to protect it from freezing. It's advisable to keep it within the temperature range of 5 to 30℃.

② Prevention of drying out

All new EDI systems undergo performance testing, and after completion, they are packaged while filled with demi. water to prevent drying inside the EDI. When storing the EDI, if the plugs are removed, the sealed demi. water inside may leak out, causing the ion exchange resin and membrane within the module to dry out, resulting in critical damage to the EDI. Therefore, ensure that the plugs attached to each nozzle of the EDI are securely connected and sealed.

③ Prevention of direct sunlight and UV exposure

EDI should not be exposed to direct sunlight or UV radiation for prolonged periods. It should be stored indoors or in a suitable storage area with the humidity being maintained at around 40~60%, preferably with air conditioning.

④ Handling and storage in terms of appearance

EDI must be protected from physical impacts such as vibration, twisting, and dropping. Prior to installation, store the EDI in its packaging to protect it from physical impacts and potential damage.

5.2 Usage Precautions

1) Precautions during initial operation

Before connecting the EDI, ensure that the entire system and pipelines are thoroughly flushed to prevent the ingress of impurities, abrasive materials, oily substances, etc., into the EDI. During EDI operation, verify the operation of the rectifier to ensure sufficient regeneration of the ion exchange resin within the module.

2) Prevention of contact with organic solvents and acid solutions

Be cautious not to come into contact with solutions containing polar solvents, organic solvents, chlorides, or concentrated acids. Store it in a way that prevents the housing surface from coming into contact with chemicals and prevents chemicals from entering the modules.

3) Caution regarding abrasive substances

Be cautious of abrasive materials that can result in wear, as introducing abrasive substances like grinding debris into the modules can result in irreparable damage to the EDI membrane.

5.3 Caution When Shutting Down (Shutdown)

The EDI system's regeneration efficiency of ion exchange resin improves with continuous operation, leading to better processing performance. Therefore, it is advisable to avoid stopping operation for more than 3 days whenever possible. If the operation is halted for over 3 days, more operating time may be required and extended electrical regeneration may be required to achieve the initially satisfactory treated water quality upon restart.

1) Short-term storage within the EDI stack (5~30 days)

① Flushing: While flushing with demi. water, perform venting to ensure there is no air inside the EDI stack.

② After filling the EDI stack with demi. water, close all valves to prevent the entry of air.

③ Alternate operations should be conducted within a week to prevent microbial growth.

2) Long-term storage within the EDI stack (30 days or more)

The storage procedure is similar to short-term storage, but it is recommended to repeat the procedure on a monthly basis.

6. EDI SYSTEM TROUBLE SHOOTING

6.1 Influence Factors

1) Temperature

① Impact of temperature

The optimal temperature for the EDI feed water is 15~35℃ and deviating significantly from this range can lead to a deterioration in produced water quality.

Temperature	Impact
Increase	As the temperature increases, the resistance within the EDI decreases, resulting in higher ion activity and relatively higher current flow even at the same voltage. Electricity conducts more efficiently, leading to the rapid removal of ions and resulting in better and faster produced water quality.
Decrease	As the temperature decreases, the resistance within the EDI increases, resulting in a relatively lower current flow even at the same voltage. Therefore, under the same voltage, ion removal is not as efficient. In other words, to achieve the appropriate current flow, higher voltage is required when the feed water temperature is lower than when it is at a higher temperature. Failure to meet this requirement can lead to a deterioration in produced water quality. Generally, under consistent other conditions, the module resistance changes by approximately 2% for every 1℃ change in temperature.

② Dealing with Temperature Changes

If the temperature deviates from the optimal range, the produced water quality may deteriorate, so adjusting the voltage is necessary. Although the most efficient range is within 15~35℃ for the feed water, there won't be significant performance changes even at temperatures below 15℃ or above 35℃ as long as they don't deviate significantly from the optimal temperature. The differences in power efficiency are also negligible.

Temperature	Impact
Increase	Within the optimal temperature range, as the temperature increases, the movement of ions becomes smoother even at relatively lower voltages, allowing for low-voltage demi. water production and aiding power efficiency. However, if the temperature significantly exceeds the optimal range, the produced water quality may deteriorate. Therefore, within the range that meets the treated water guarantee levels, gradually reduce the voltage or current. - During constant voltage operation, gradually decrease the operating voltage by about 20~30V. - During constant current operation, gradually decrease the operating current by about 0.1~0.2A.
Decrease	As ion movement becomes less efficient, higher voltage is required, leading to decreased power efficiency and potentially negative impacts on operational costs. Therefore, within the range that meets the treated water guarantee levels, gradually increase the voltage or current. - During constant voltage operation, gradually increase the operating voltage by about 20~30V. - During constant current operation, gradually increase the operating current by about 0.1~0.2A.

2) Pressure

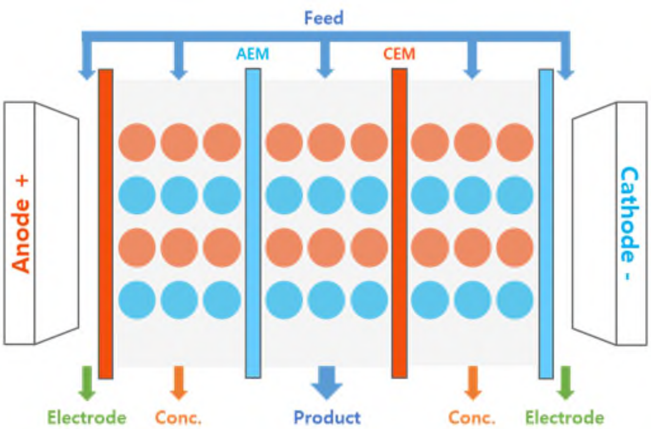
The operating pressure of EDI is divided into Feed IN, Concentrate IN, Concentrate OUT, and Product OUT.

The produced water outlet pressure (Product OUT) must be maintained from 0.5 to 1.5 bar higher than the concentrate water pressure. This is to prevent highly concentrated water from entering the produced water, ensuring better-treated water quality. The optimal operating pressures for each flow are as follows

Flow	Optimal Operating Pressure
Feed Pressure	4.0 ~ 4.5 kgf/㎠
Conc. In Pressure	3.0 ~ 3.5 kgf/㎠
Product Out Pressure	2.5 ~ 3.0 kgf/㎠
Conc. Out Pressure	1.5 ~ 2.0 kgf/㎠

3) Electrode Water

Electrode Water refers to the water that flows between the anode plate (+) and the cathode plate (-) located at each end of the EDI and the ion exchange membrane. Electrode water cools the heat generated at the electrode plates, facilitates the smooth discharge of gases produced in the electrode chamber, and minimizes contamination such as scale generated in the electrode chamber during prolonged operation. To achieve this, it is recommended to ensure a discharge rate of at least 60 L/hr. If the valves attached to the inlet and outlet of the electrode water are closed or if the connecting tubes are damaged, and the electrode water supply is interrupted, it can result in severe damage to the electrode plates. In such cases, replacement of the EDI might be necessary, so caution should be exercised.

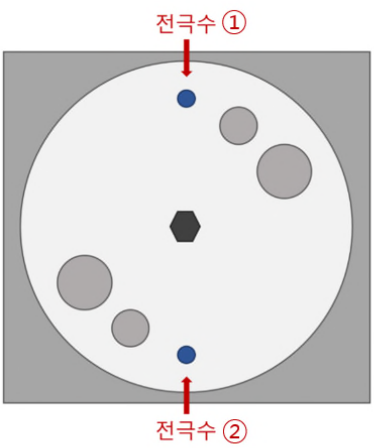


<Figure 6.1 Electrode Water>

For the TN & TU Series EDI, there are two methods for discharging electrode water: one is to discharge electrode water separately from the concentrate water, and the other is to discharge electrode water mixed with the concentrate water. In cases where electrode water is discharged while mixed with the concentrate water, there is no separate electrode water piping. It is introduced and discharged through the concentrate water piping. Therefore, there is no need to consider a separate piping system for electrode water.

In cases where electrode water is discharged separately from the concentrate water, the inlet and outlet piping for electrode water varies in location depending on the model. The model-specific piping locations provided below are for the standard of each model; however, the actual locations may vary depending on the installation site, even for the same model.

Figure 4.2 is standard electrode water piping location. It should be connected from ① to ② using PE tube to supply feed water to the electrode chamber.



<Figure 4.2 Electrode Water Piping Location>

It is recommended to use P.E material for the electrode water connection piping, and caution should be taken with SUS material due to the possibility of long-term operation causing electrical and chemical (caused by chemical cleaning) corrosion. However, for the regions with water temperatures exceeding 40°C, such as in the Middle East region, it is recommended to use heat-resistant PP tubes.

4) Voltage

① The role of voltage

- Power source to move ions

Voltage acts as a power source to move the ions in the dilute spacer to the concentrate spacer. Feed water is introduced into the spacer located between the membranes. Upon applying an electric current, electrostatic forces cause cations in the water to move toward the (-) electrode and anions to move toward the (+) electrode. During this process, the cations (Na^+, Ca^{2+}, etc.) present in the dilute spacer pass through the cation exchange membrane, while the anions (Cl^-, OH^-, etc.) pass through the anion exchange membrane and move to the concentrate spacer.

- Water splitting

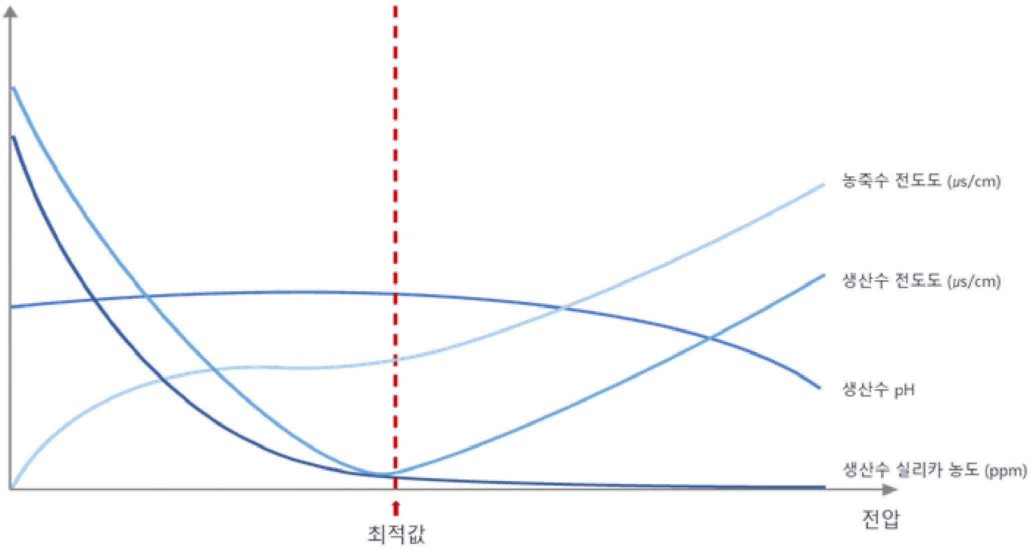
It causes water splitting (H_2O to H^+ and OH^-) in the ion exchange membrane and ion exchange resin, resulting in the decomposition of H_2O into H^+ and OH^-. The generated H^+ and OH^- ions regenerate the ion exchange resin and assist in removing weakly ionized ions such as CO_2 and silica.

② Changes in water quality according to voltage

Voltage	Impact
Increase	The power source of ion movement decreases, causing impurity ions present in the feed water to have less power to pass through the ion exchange resin and ion exchange membrane. As a result, ions may not move from the dilute spacer to the concentrate spacer, leading to a decrease in ion removal efficiency. This directly correlates with a deterioration in treated water quality.
Decrease	Excessive water splitting reduces the efficiency of ion removal, and the excessive power pulling ions towards the electrode plates on both sides of the EDI leads to back diffusion of ions from the concentrate spacer to the dilute spacer, resulting in a deterioration of the treated water quality.

③ Optimal voltage

The typical operating voltage is set to the lowest possible operating voltage that meets the silica guarantee levels of the treated water. However, if the concentration of silica in the treated water increases due to degradation of EDI performance caused by deterioration in the quality of EDI feed water or prolonged usage, the operating voltage should be increased to a higher level. In this case, it is sequentially increased in intervals of 30~50V.



<Figure 4.3 Relationship between Voltage and Product Water Quality>

5) Current

① The role of current

Current refers to the flow of an electric charge, which is the amount of charge passing through a cross-sectional area per unit of time. In the context of EDI, the current value is directly proportional to the total number of ions moving from the dilute spacer to the concentrate spacer. In this context, ions encompass impurity ions (Na^+, Cl^-) present in the feed water and ions (H^+, OH^-) generated from water splitting.

According to Ohm's law (V=IR, where V=voltage, I=current, and R=resistance), when the resistance inside the EDI is low, the current flows well, and when the resistance is high, the current faces difficulties in flowing, which in turn hinders ion movement. Therefore, EDI needs to have an appropriate current flowing to ensure normal operation and performance of the produced water.

② Influence of current

If the current in the EDI exceeds the expected value, it can be attributed to factors such as the high conductivity of the feed water, excessive water splitting due to overvoltage, or reduced concentrate flow rate.

- Feed Water Conductivity

  The current is partially proportional to the feed water ion capacity (TDS or ㎲/㎝). If there are numerous ions in the feed water, the current increases, indicating good electrical conduction and low resistance.

- Voltage

  Water splitting increases nonlinearly with voltage. As overvoltage leads to excessive water splitting and the production of H^+ and OH^- ions, the current value increases.

- Concentrate Water Flow rate

  The current varies according to the concentrate water flow rate (module recovery). On average, the concentrate water flow rate is 10% of the feed water flow rate. If the concentrate water flow rate is lower than the recommended range, the current value and the conductivity of the concentrate water increase.

6.2 Trouble Shooting

1) Deterioration in Treated Water Quality

Problem	Action
Increase in Feed Water TDS (including CO_2, Silica)	① Constant-voltage operation – Sequentially increase the operating voltage by around 20~30V. ② Constant-current operation – Sequentially increase the operating current by around 0.1~0.2A. ※ Adjust within the range that meets the treated water guarantee levels.
Decrease in Feed Water Temperature	
Increase in Feed Water Temperature	① Constant-voltage operation - Sequentially decrease the operating voltage by about 20~30V. ② Constant-current operation - Sequentially decrease the operating current by around 0.1~0.2A. ※ Adjust within the range that meets the treated water guarantee levels.
Increase in Feed Water Hardness	① Reduce the recovery rate. ② Cleaning or replacement of R/O membrane in EDI inlet-side (to lower feed water hardness and silica concentration)
Product Out / Concentrate Out Pressure Change	Keep the treated water pressure (Product) higher than the concentrate water outlet pressure (Conc. out) at all times. ※ Sequentially adjust the pressure difference within the range that satisfies the treated water guarantee levels; typically, this difference is around 0.5~1.5 bar.
Electrical wiring condition	Check if the (+) and (-) electrode wires of the electrode connection are properly connected.
Contamination in EDI modules	Chemical cleaning (CIP) is required.
Others	Adjust the feed water flow rate of the EDI module with deteriorated treated water quality to a lower level, and adjust the feed water flow rate of the EDI module with better-treated water quality to a higher level. ※ Adjust within the range that meets the treated water guarantee levels.

2) Decrease in Treated Water Flow Rate

Problem	Action
Valve Operation Error	① Adjust Feed in & Product out Valve → Increase in product water flow rate ② Adjust Conc. in & Conc. out Valve → Adjust according to the design recovery rate
EDI Module Oxidation	Check for oxidation - Analyze the ORP and Cl_2 of the feed water
Contamination inside the EDI Module	Check for organic and microbial contamination - Analyze TOC/COD and microbial of feed water If contamination occurs within the module, chemical cleaning (CIP) is required

3) Rectifier Issue

Problem	Action
OV alarm lamp display (Over-Voltage)	① Check if it has exceeded a voltage of 660. ② Adjust the limit voltage value to be below a voltage of 660V
OV alarm lamp display (Over-Current)	① Check if the rated output current (5A or 10A) exceeds 10% (5.5A or 6.6A or above). ② Set the rated output current not to be exceeded and adjust it to the limit current value
Fuse alarm lamp display	① Occurs when there is a malfunction in the internal SCR fuse of the rectifier. ② Replace the faulty fuse. ③ If it is not due to long-term usage, check if there is an issue with the EDI module.
INP alarm lamp display (Input voltage, Rated input voltage)	① Check if the rated input voltage (AC 380V or 460V) is below 10% or exceeds 10%. ② Adjust the AC input voltage to be within the 10% range. ③ Adjust the rectifier's allowable AC input voltage range to be as wide as possible. ④ Modify the program to prevent the rectifier from stopping even when INP occurs. ※ Depending on the manufacturer, INP occurrence may result in an alarm without stopping the rectifier.
OT alarm lamp display (Over-Temperature)	① Check if the SCR operating temperature exceeds the specified limit of 85°C. ② Replace the malfunctioning fan (either the rectifier's internal fan or the enclosure fan)

Problem	Action
Interlock issue	① Verify if the feed water flow rate is below the set value. ② Verify if the concentrate water flow rate is below the set value.
EDI module issue	① Check for any damage to the electrical connection wires due to EDI module problems. ② Replace the EDI module or the damaged electrical wires.
Mainboard malfunction	Replace the main board
Display board malfunction	① If there is a discrepancy between the set voltage/current values and the actual voltage/current values, the voltage and current supply may not be established. ② Replace the display board
Remote control of the rectifier is not functioning.	① Verify the position of the rectifier's Local/Remote selection switch. ② Check the status of the rectifier communication cable connection. ③ Check if there are any issues with the rectifier controller.
Treated water flow rate is below low	Turn off the rectifier
Concentrate water flow rate is below low	Turn off the rectifier
Treated water flow rate is above the set limit	Turn on the rectifier

4) Decrease in Concentrate Water Flow rate

Problem	Action
Valve Operation Error	Adjust Conc. In & Conc. Out Valve → Adjust according to the design recovery rate
Contamination inside the EDI Module	Chemical cleaning (CIP) is required.

5) Decrease in Electrode Water Flow rate

Problem	Action
Valve Operation Error	Check if the electrode water inlet valve and electrode water flow meter valve are in an open state
Contamination inside the EDI Module	Chemical cleaning (CIP) is required.

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