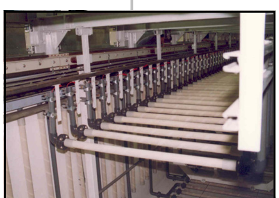
Technical Reference

Topic: Membrane Electrode System Specification Guide

The TECTRON™ Membrane Electrode (ME) Cell is one part of the Membrane Electrode System. This Bulletin lays out a design specification guideline, which is followed by a discussion of each section of the guideline. Where appropriate, options to the specification will also be mentioned.



Summary

Approved Materials: Use only materials specifically approved by the vendor of the E-coat paint.

Design Specification: A basic Membrane Electrode System specification shall include the following major items: TECTRON Membrane Electrode Cells, electrolyte holding tank, electrolyte circulation pump, conductivity & other system controls, piping, mechanical support, electrical connection, and DI water or RO water supply.

Membrane Electrode Cells: Use the 4:1 Ratio, Average Electrode Current Density, or Average Center to Center method(s) to calculate the amount of Electrode area. Electrode O.D. and effective length determine the effective surface area of each Membrane Electrode Cell. Round up to an even number of Cells so there are the same amount on each side of the E-coat tank.

Electrolyte Holding Tank: XLPE Poly tank with magnetic drive pump or 304 stainless steel with a vertical pump. Tank volume should approximate the electrolyte volume in all the ME Cells.

Circulation Pump: Horizontal magnetic drive or vertical CPVC pump with a rating capable to supply 8 lpm/m^2 (~2 gpm/10 SF) [plus 20% reserve]

Controls: Conductivity controller operates DI/RO water valve to dilute electrolyte when necessary.

Piping: PVC supply and return manifolds.

Mechanical Support: Rub rails, Cell support, and other related items.

Electrical Connections: Quick disconnects for cable leads, compression washers, and diodes for multi-zone systems.

DI Water: Meet necessary quality level and have adequate flow rate. Include a carbon filter and either a UV light or ozone generator to reduce the occurrence of fungus and other biologicals in the electrolyte solution.

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The function of the Membrane Electrode System is to provide the opposing electrode, which drives the E-coat paint process and also to maintain the proper pH of the E-coat paint bath.

General Background

A Membrane Electrode System shall include the following items: TECTRON Membrane Electrode Cells, holding tank, circulation pump, conductivity & other controls, plumbing, mechanical support and protection, electrical connections, and DI/RO water source.

The function of the Membrane Electrode System is to serve as the opposing electrode and also maintains the proper pH of the ED paint bath. With cathodic ED paints the Electrode is the anode (i.e. the ware is the cathode) and the Membrane Shell removes anions (i.e. small negatively charged ions). For anodic ED paints the Electrode is the cathode (i.e. the ware is the anode) and the Membrane Shell removes cations (i.e. small positively charged ions)..

Direct current is supplied by a DC rectifier to each Cell. Current is then transmitted through the electrolyte solution, ion-exchange membrane, paint, and eventually the deposited E-coat paint film. The current then travels back to the rectifier through the carrier, conveyor, brushes, and cables.

A pump circulates an electrolytic fluid called "electrolyte" because it is comprised of ions and DI/RO water. This fluid is responsible for transporting the ions removed from the paint bath to drain. It also cools off the face of the electrode because there is heat generated in this process and also must scrub off oxygen which is generated on the anode for cathodic paints). Note that there is generally no separate heat exchanger for the electrolyte. For Cathodic ED paint systems the electrolyte is called 'anolyte' and for anodic ED systems the electrolyte is called 'catholyte'.

A conductivity controller continuously monitors the electrolyte conductivity (units are Siemens/cm or Mho/cm). The controller instructs a DI/RO water solenoid valve to open when the conductivity rises above a set point. The tank has a natural overflow opening, which allows excess electrolyte to leave the system and thus the electrolyte's conductivity is diluted. When the controller senses a level below the set point, the valve closes.

First Class Quality & Approved Material

All material and workmanship shall be first class. The following materials are generally approved for use with E-coat paint: PVC; 304 stainless steel (except for Electrodes, which are to be 316L stainless steel, precious metal oxide coated titanium, or conductive ceramic); polypropylene; polyethylene; hypalon; viton; Teflon; neoprene; and EPDM. If there is any question, then the E-coat paint supplier should be consulted first

Electrode Area

The amount of Electrode surface area shall be calculated using the **4:1 Rule**, which states that the Electrode surface area shall equal one-quarter of the total painted surface area that passes one point in a two (2) minute period. See the example below:

<u>Work Area Basis (WAB) = Area/Job x Jobs/Hour x 60 min/Hour x 2 min</u>

<u>Electrode Area (EAB) Basis = WAB / 4</u>

This methodology provides good results as long as the expected dwell time is about 2 minutes and the desired E-coat film thickness is about 25 microns (1 mil). If your deposition time is less than 2 minutes or you want more than 25 microns (1 mil) of E-coat thickness then the 4:1 Rule will undersize the EAB. Likewise if you have more than 2 minutes or want less than 25 microns (1 mil) then the 4:1 Rule will oversize the EAB. In these cases, an

Alternate criteria must be employed. In this case the expected maximum amps are estimated and the amount of Electrode Area can be suggested by using the **Electrode Current Density Rule.**

First, the paint deposition factor (amp-minute/m^2-micron, or amp-minute/SF-mil) must be known. TECTRON™ Cells have been operated for many years now up to levels of 55 amps/m^2 (approximately 5 amps/SF). The calculation is as follows:

Estimated Current= painted through-put rate x deposition factor x film thickness

For high speed, high painted through-put systems, such as appliance or automotive E-coat paint systems the typical Electrode current densities are set to about 35 amps/m^2 (approximately 3.25 amps/SF). This allows for fault tolerance and a longer life time of the equipment. For smaller and slower through-put E-coat paint systems the typical Electrode current density is higher, which means the equipment will not last as long and there is less fault tolerance.

Some automotive firms have revised their specifications and now require the use of 2.5 minutes (not 2 minutes) when employing the 4:1 Rule. This will increase the recommended electrode area by 25%.

Membrane Electrode Cells

The Membrane Electrode Cells shall be TECTRON Cells manufactured by UFS Corporation. The only metallic portion shall be the Electrode. All other components shall be made from entirely non-metallic, light-weight, non-conductive materials. The ion-exchange membrane shall be selected based upon the type of ED paint and the expected duty cycle. The Electrode shall be selected in a similar manner .

The effective length of the side Cell shall be at least as tall as the height of the work package envelope. If possible, the effective length of the Cell should be equal to the height of the work package + submergence (distance from liquid level to top of work package envelope) + 50 mm (2”). The Cell can be made in any length up to 2.9 m (114.2 in), or longer, with the standard lengths shown below

TECTRON Small Diameter Cells

1-1/2” size with an OD of 48.26mm (1.900 in)

Effective Length /	Surface area sq. meters (SF)
910 (35.8)	0.138 (1.49)
1400 (2.86)	0.212 (2.28)
1900 (75.8)	0.288 (3.10)
2300 (90.6)	0.349 (3.75)
2900 (114.2)	0.440 (4.73)

Recommended maximum Center-to-Center 750mm (30in)
Recommended minimum Center-to-Center 150mm (6 in)

2” size with an OD of 60.33 mm (2.375 in)

Effective length /	Surface area sq. meters (SF)
910 (35.8)	0.172 (1.86)
1400 (55.1)	0.265 (2.86)
1900 (75.8)	0.360 (3.88)
2300 (90.6)	0.436 (4.69)
2900 (114.2)	0.550 (5.92)

Recommended Maximum Center to Center 950 mm (36 in)
Recommended Minimum Center to Center 200 mm (7.4 in)

Cells can also be joined together to create very long ME Cells up to about 6 m (236.3 in).

TECTRON Large Diameter Cells

UFS introduced large 5 in diameter TECTRON Cell in the 2003 and followed up with a 3 inch Cell the next year.

3" size with an OD of 88.9 mm (3.5 in)

Effective Length /	Surface area sq. meters (SF)
910 (35.8)	0.251 (2.71)
1400 (2.86)	0.391 (4.21)
1900 (75.8)	0.531 (5.71)
2300 (90.6)	0.642 (6.91)
2900 (114.2)	0.810 (8.72)

Recommended Maximum Center to Center 950 mm (36 in)
Recommended Minimum Center to Center 300 mm (11 in)

5" size with an OD of 141.3 mm (5.563 in)

Effective Length /	Surface area sq. meters (SF)
910 (35.8)	0.404 (4.35)
1400 (2.86)	0.621 (6.69)
1900 (75.8)	0.843 (9.08)
2300 (90.6)	1.021 (10.99)
2900 (114.2)	0.1.287 (13.86)

Recommended Maximum Center to Center 2250 mm (36 in)
Recommended Minimum Center to Center 450 mm (17.5 in)

In a conventional Membrane Electrode System the Cells are placed along the side walls of the ED tank. The number of Cells can then be easily established:

Number of Cells= Electrode area ¸ area/Cell + 2 Cells= m^2 ¸ m^2/Cell + 2 Cells (round up to an even number)

Newer ED systems as well as higher through-put systems are employing Electrode cells not only on the side walls of the ED tank, but also on the floor and above the roof of the auto body. This is being done for several reasons: reduce paint consumption, improve film build on roof and interior, and lower energy consumption.

Cell Layout Spacing - Monorail

The first Cell is placed at the end of the Pre-wet Zone, which is generally 10 to 20 seconds past the point where the ware is fully submerged (Last Point I, [LPI]). The last Cell is generally at the point where the ware breaks thought the liquid level (First part Out [FPO]).

The first 3 to 5 Entrance Cells (or at each new voltage zone) should be at the minimum spacing. The spacing of the last two Cells at the exit should be at the 2 times the minimum or less. The balance of in the Cells in the middle should be spaced accordingly. However the spacing in the last portion of the zone should not be greater than that of the middle.

Cell Layout Spacing - Hoist

Cells are generally placed along the two long sides of the ED tank. For ED tanks with an aspect ratio closer to 1 (i.e. square tank as seen in the plan view) Cells can be placed on all four walls. In either situation, the Cells generally begin near the placement of the edge of the ware and extend to the other edge of the ware. Cells should not be placed closer together than the minimum spacing.

Floor and Roof Electrode Spacing

Generally placement of these types of Cells (or bare Electrodes) are placed a minimum of 50 mm (2 in) away from any vertical moving conveyor part or 150 mm (6 in) away from any conveyor part that can swing side to side. Also keep Electrode/Membrane surface at least a minimum distance of 30-50 mm (1 - 2 in.) below liquid level and 180-200 mm (7 - 8 in.) away from top of ware.

Floor

Electrolyte Holding Tank

The holding tank shall be constructed from 304 stainless steel. All wetted seams shall be double-welded. A baffle shall be used to separate the pump from the returning electrolyte. A tank skimmer shall be used to remove floating debris. It shall have a removable lid for inspecting the inside of the tank. A strainer shall be fitted to the inlet of the tank (from the return manifold) above the usual liquid level. A stainless steel stud shall be welded to the tank for grounding purposes.

Alternatively a molded XLPE poly tank can be used to hold the electrolyte solution. Make one of the pump suction piping sections from a 304 stainless steel material and weld the grounding stud to this stainless component.

Circulation Pump

The pump shall be a seal-less type vertical CPVC style (for use with the stainless holding tank). The pump flow rate shall be calculated by using 8 lpm/sm (2 gpm/10 SF Electrode area) and then adding 20% as a safety factor. The pump head capacity shall be at least 1.5-2 bar (22-28 psi), more if the pump is located more than 3 meters (10 feet) below the rim of the ED tank. There shall be a pump by-pass loop back to the holding tank with a throttling valve. The electric motor shall be 3 phase, 460 volt, TEFC style. <u>The required flow rate for any horizontal Cell needs to be about twice, or 16 lpm/sm (4 gpm/10SF) in order to completely purge oxygen for the Cell.</u>

Alternatively the pump can be a horizontal magnetic drive type pump.

Electrolyte Controls

The electrolyte circulation system shall be fitted with the following controls: 0-20,000 (or 0 to 2000 milli Siemens/cm) microSiemens/cm analog conductivity controller, plastic/stainless steel conductivity sensor, 0-2 bar (0-30 psi) guarded pressure gauge, roto-meter / total flow electronic meter, check valve, main control valve (NO), 110 volt DI water solenoid valve, low tank level switch, and tank drain valve. The conductivity controller should be located near eye level about 1.5 m (5') away from the holding tank.

Electrolyte Manifold Piping

All piping shall be PVC. Supply Manifold branch piping (i.e. on each side of the ED tank) shall be at least a PVC 50 mm (2") Schedule 80 minimum and sized so that the average flow rate is no more than 0.25 – 0.5 meters/sec (3 –5 ft/sec). The size of the Supply Manifold main trunk piping to the Tee (i.e. where the branch piping begins) should be at least one size larger than the branch piping.

The Return Manifold branch piping shall be at least 75 mm (3") PVC Schedule 40 minimum with PVC DWV type fittings. It shall be sloped downwards (i.e. towards the electrolyte holding tank) at a 21 mm per meter (¼ in per foot) slope and sized so the branch piping is never more than ¾ full. The size of the Return Manifold main trunk piping to the Tee (i.e. where the branch piping begins) should be at least one size larger than the branch piping. A 0-2 bar (0-30 psi) guarded pressure gauge shall be placed at the termination of each supply manifold leg. A siphon-breaker shall connect the supply and return manifold and there shall be at least a 50 mm (2") vent located 200 mm (8") above the top of the Cells.

Mechanical

Small Diameter Cells -The side Cell support strut channels shall be 41 mm square (1.625”) and made from steel. Cell support channels shall be supported at least every 1.5 m (5’) and be space 150 mm (6 in) center to center. Two-piece clamps (use two clamps for each Side Cell) shall be used to attach Cells to the strut channels.

Large Diameter Cells - These Cells can use the strut channels as described above or they can they can be fitted with a Universal Bracket and be mounted in the same fashion as a box cell or C cell to the rim of tank.

Supply and return manifolds shall be supported with the same type of strut channel every 1.5 m (5’). Metal two-piece clamps should be used to attach the manifolds to the strut channel.

There shall be a FRP or PVC Schedule 80 (no more than 50 mm [2 in) OD) rub rail located such that there is at least 250 mm (10”) gap, minimum from the ED tank wall to the rub rail.

The Electrolyte holding tank shall be placed on a flat, level pad as close to the ED tank as possible.

Electrical Cables

Each Cell shall have a cable made THHN, THWN-2, Oil and gasoline resistant, MTW, or DLO (i.e. welding) type insulation. and be sized for at least 125 amps/sm (12 amps/SF) of Cell Electrode surface area. All washers shall be made from stainless steel and be a compression type. There shall be a quick connect built into the cable lead for each Cell (does not apply to Hoist type ED tanks). Several Cell cable leads may be ganged together into a copper set screw lug. For systems with more than one voltage zone, diodes shall be used with the

Cells in the lower voltage zone require a diode if the electrical design features a split anode bus bar design. The rating of the diode shall be twice the application voltage and 1.5 to 2 times the application amperage.

DI/RO Water

The supply of De-ionized (DI) or Reverse Osmosis (RO) water shall be 60% to 80% of that of the electrolyte circulation pump. There shall be a UV light source on the incoming water to minimize the existence of bacteria and fungus. There shall be a means to easily clean the quartz sleeve that protects the UV bulb. DI water quality shall meet the requirements of the ED paint manufacturer. A carbon filter is required to remove organic matter from the feed water.

DI/RO water usage is a function of the following variables: coulombs consumed by the ED system, electrolyte conductivity setpoint; MEQ value of the replenishment ED paint; and the specific neutralizer used in the ED paint.

Discussion of Components

Holding Tank –The function of the electrolyte holding tank is to act as a reservoir, in order to maintain a near steady-state conductivity level and also cool (from the ambient) the electrolyte fluid. The volume of the tank should approximate the total volume of the electrolyte in all the Cells. The smallest tank volume should be about 100 l (25 gal).

The baffle keeps foam away from the pump and the skimmer removes floating debris. A nylon, or equal, strainer bag, maybe 40 mesh or less, is used to collect dead fungus. The bag should be located above the liquid level so a maintenance person can easily remove and clean it. The tank needs to be grounded to avoid potential electric shock injury.

Circulation Pump – A standard single mechanical horizontal pump is not recommended because if there is ever a membrane cut, paint solids will enter the Membrane Electrode System and cause fast wear on the pump seal. A vertical CPVC pump, on the other hand does not use mechanical seals and is not affected by contaminated electrolyte solutions. The pump suction piping should be one size larger than the suction opening of the pump. It should include a foot valve (no butterfly check valves) and inlet strainer. The electric motor should be a 3 phase, 460 volt, and TEFC style.

Generally the more electrolyte flow the better because this creates: greater turbulence inside the Cell (scrub oxygen off face of electrode) and more cooling of the Electrode, which lead to greater life. <u>Note that for Low Profile Cells (i.e. those Cells with a Bulkhead Fitting) the pressure drop across the Cell should be less than ½ Bar (7 psi) to avoid damage to the membrane.</u>

Ion-exchange membrane -There are two basic choices: a common grade (standard, or UFS sales code 'PTAR' for cathodic E-coat paints) roll style membrane or pressed (upgrade, or UFS sales code 'PTAN' for cathodic E-coat paints) style. The roll type is less costly and often an economical choice for customers who perform regular maintenance on their ME Cells. Pressed style is more costly to cure and is considered an upgrade.

Both roll and pressed style membrane begin the manufacturing process the same. Namely the polyethylene cloth, binder, and ion-exchange resin are the same. The difference is found in the curing stage. The roll style cures while the sheet is being processed. Alternatively, with the pressed style process, the raw membrane is cut to the length ordered, and placed into a hydraulic press between sheet separators. The press is then rolled into an autoclave where the membrane is cured under high pressure and high temperature.

Roll membrane is suitable for open top ME Cells and light duty painting in hoist systems. Pressed membrane is strongly recommended for closed top ME Cells under elevated pressure in heavy duty hoist systems, or in conveyor systems where Cells are working continuously and back diffusion from excess membrane permeability can create a problem.

Adding a chiller to the Electrolyte Circulation System - Some persons have reported success will reducing/eliminating fungus in the electrolyte when the electrolyte fluid is cooled to 18 deg C (68 deg F). Discuss this with your E-coat machine engineer or paint supplier. The issue is that we do not want to overcool the paint and so the heat exchanger operation may have to be lessened since some of the cooling may now be taken place by the colder electrolyte flowing inside of all the Membrane Electrode Cells.

Bag Filters - are not recommended for electrolyte recirculation systems for two reasons. The first is that the bag filter media itself forms a framework for organisms to grow and thrive upon and the second is that if the bag filter fills up with fungus the flow may be slowed down of stopped, which lead to over-heating of the electrodes and shorten lifetime.

Precious metal anodes - These are either ruthenium oxide-coated titanium or iridum oxide-coated titanium. Iridium seems to be a better choice for many applications. Precious metal Electrodes can not be used as a cathode since the coating can spall off.

Cathode material - For anodic tanks the opposing electrode is the cathode and the ware is the anode. In this case the material for the anode can be black iron pipe since there is no corrosive electrical activity like exists at the anode.

Some equipment options are listed below -

Electrical Current Monitoring

Each Cell shall have its own DC current sensor. The output should be sent back to a panel mounted ammeter or a data acquisition system that can collect all the data, isolate the signals and send the real time data to a PC.

Ripple Monitor

The output of the DC rectifier shall have a AC Ripple Meter that measures the AC voltage in the DC output. This value should be less than 1% typically.

Auto Voltage Controller

The voltage output of the DC rectifier shall be controlled by an Auto voltage Controller that monitors the current output and adjust the voltage to maintain a pre-determined E-coat film thickness. It shall have the ability to manage more than 1 film thickness and must have a means to tell the controller which film thickness recipe to use if more than 1 recipe is to be used.

Drawings & Schematics

Navigate to our website at
http://www.ufsc.com/
And then click on downloads to view typical General Arrangement drawing of Membrane Electrode Cells and general flow schematics.

For More Information

Visit http://www.ufsc.com/ and make sure to look into the topics available for download.