WIRE EDM DEIONIZING RESIN

F U N D A M E N T A L S

WEDM Dielectric Basics

Prior to plunging into the details of deionizing resin and regeneration, let's first examine the role of the deionized water dielectric in a Wire EDM. Deionized water serves as the dielectric in a Wire EDM just as oil serves as the dielectric in a Sinker EDM. The role of the dielectric is to serve as a medium through which the discharge occurs, solidify and flush away the debris from the wire and the work piece, and keep the wire cool. The role of the dielectric in serving as the medium for discharges is our primary concern in this article. The dielectric serves a dual role as both an insulator and a conductor. Prior to the discharge, the deionized water acts as an insulator, allowing the electrical potential between the wire and the work piece to build without it bleeding off through the fluid. Once the electrical potential between the wire and the work piece builds to a certain intensity, the dielectric breaks down and forms an electrically conductive path (known in EDM as the Discharge Channel). This conductive path allows the energy of the spark to be transferred from the wire to the work piece for metal removal. The role of the Discharge Channel is crucial in assuring that each discharge is the same, affecting cutting speed, surface finish, and slot width. Thus maintaining a constant condition of the deionized water dielectric is essential to obtaining consistent results from the Wire EDM process.

WEDM Dielectric System Basics

The function of the dielectric system is to maintain a constant condition of the deionized water in the machine. The electrical discharge process contaminates the water in two ways. The most obvious contamination produced by a discharge is the re-solidified wire and work piece material that is the product of the discharge – the solid contaminant. The solid contaminant is removed by the filter subsystem of the WEDM dielectric system. A less obvious, but very significant, contamination produced by a discharge is the dissolved contaminant. The dissolved contaminant consists of metal salts produced during the discharge that dissolve into the water just as table salt dissolves into water. These dissolved salts increase the conductivity of the water, causing spark energy to bleed off prior to the actual occurrence of the discharge, adversely affecting the consistency and efficiency of the discharge. These contaminants also contribute to accelerated corrosion of work pieces, tooling, and the machine itself. The dissolved contamination is removed by the deionizing subsystem of the WEDM dielectric system. The deionizing subsystem consists of a pump, control system, and a deionizing container. The level of conductivity of the water in the clean tank of the dielectric system is monitored by the control system which activates the pump which forces water from the clean tank through the deionzing container and returns it to the clean tank. The deionizing container contains deionizing resin which removes the dissolved contamination from the water.

Deionization by Ion Exchange

The process of removing the dissolved contamination from the water is called Ion Exchange. The dissolved contamination in the water consists of ions. Let's use the commonly known metal salt sodium chloride (table salt) as an example. When table salt is dissolved in water, the solid grains of salt disassociate into positively charged sodium ions and negatively charged chloride ions. Positively charged ions are also known as cations, and negatively charged ions are also known as anions. In the process of ion exchange, dissolved or ionic contamination is removed by passing the water through a media which contains beneficial donor ions which are exchanged with the contaminant ions. Specifically, the media consists of a mixture of resin beads (called cation) to which positively charged hydrogen ions are attached and resin beads (called anion) to which negatively charged hydroxide ions are attached. Using our example of water contaminated by dissolved table salt as an example, the positively charged sodium cations in the water are exchanged with the positively charged hydrogen ions attached to the cation resin beads and the negatively charged chloride ions in the water are exchanged with the negatively charged hydroxide ions attached to the anion resin beads. The net result is that the contaminant ions are now attached to the resin beads and the donor hydrogen (H+) ions and donor hydroxide (OH-) ions are now dissolved in the water. However, the H+ ions and the OH- ions immediately combine to form H_2O or pure water.

Deionizing Resin

As mentioned in the prior paragraph, deionizing resin consists of cation and anion resin beads. Resin beads are porous, chemically inert polystyrene beads that are chemically treated. These beads ***(See Fig #1)*** are small, highly porous spheres. The porous structure provides a multitude of sites for ions to become attached during subsequent chemical treatments. It is only after chemical treatment that a bead becomes anion or cation. In order to make a cation bead, the inert polystyrene bead is subjected to a treatment with an acid such as hydrochloric acid. This acid treatment puts the H+ ions on a multitude of sites on and within the porous sphere. Similarly, in order to make an anion bead, the inert polystyrene bead is subjected to a treatment with a caustic soda which puts the OH- ions on a multitude of sites on and within the porous sphere. It is important to note that, for a reason beyond the scope of this discussion, anion beads do not contain as many active ion sites as cation beads. There are two ways of deploying these beads:

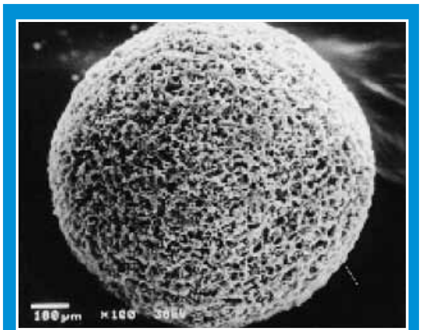

Fig #1: Courtesy of ABA Water Systems

- Dual bed – The anion and cation beads are kept in separate containers and the water is passed sequentially through the containers.
- Mixed bed – The anion and cation beads are mixed together in one container and the water is passed through the mixture.

Although early Wire EDM dielectric systems employed dual bed resin systems, most current generation machines utilize mixed bed systems.

Since the anion beads have fewer active sites available for ion exchanges, it is necessary to have more anion beads than cation beads in order to have a balanced system with equal ionic capacity. Thus, for a dual bed system, the anion container needs to be larger than the cation container. In a mixed bed system, the mixture needs to have proportionately more anion beads than cation beads. That proportion is typically 60% anion and 40% cation.

It should also be noted that the cost to produce anion resin is approximately three times the cost to produce cation resin.

Resin Properties

There are three important parameters that are used to determine the critical properties of deionizing resin:

- Water Quality: Water quality is measured by either the conductivity (Units of measure are µMhos or µSiemens) or resistivity (Units of measure are Ohms) of the water that exits a deionizing system. Conductivity and resistivity are the inverse of each other. Low conductivity or high resistivity are indications of high water quality output from a deionizing system. To get higher quality water, more extensive and expensive treatment of the beads is necessary. Mixed bed systems generally give better quality water than dual bed systems.
- Capacity: Capacity is a measure of how much ionic contamination a resin system can remove before the output water quality deteriorates. The capacity is tested by dissolving a salt into water and passing the salt water through a deionizing system. The quantity of salt dissolved in the water necessary to exhaust the capacity of the system to produce water of a known quality determines the system capacity. The weight of the salt that was dissolved into the water determines the capacity, which is typically measured in grains. The capacity of a system is influenced by both the intensity of the treatment of the beads and the volume of the beads. Volume capacity is typically measured in cubic feet. Dual bed systems generally have higher capacity than mixed bed systems of the same size.
- pH: In theory, the pH of water exiting from a resin system should be neutral, or 7. However, since the resin beads are treated with either acid or caustic agents, it is possible for the exit water to become acidic or basic if the resin beads were not properly rinsed after treatment. It is important to note that deionization alone cannot change the pH of water. Thus, if the water fed into a deionization system has a pH other than 7, the water exiting the deionization system will have the same pH. Many Wire EDM users that process carbide in their machines are very concerned about the possibility of acidic water adversely affecting the carbide. Properly rinsed resin should not add to the acidity of the water in the dielectric system. However, it should be noted that the natural interaction between the CO_2 in the air and the water in the dielectric system will produce a small amount of carbonic acid which will eventually result in a pH of between 5 and 6.

Resin Systems

There are two basic types of resin systems currently used on Wire EDM's, each of which have a cadre of ardent proponents:

- Resin Tank Systems – The typical resin tank consists of the following components: ***(Fig# 2a, 2b)***
  - Shell - Usually made of fiberglass contains the mixed bed of resin and all the system components
  - Head – Mounted to the shell via a large threaded connection and provides an attachment point for the lance, the diffuser, and the connections to the machine
  - Diffuser – Mounted under the head, the diffuser distributes the

Fig #2a: Fiberglass resin tank courtesy of The Resin Exchange

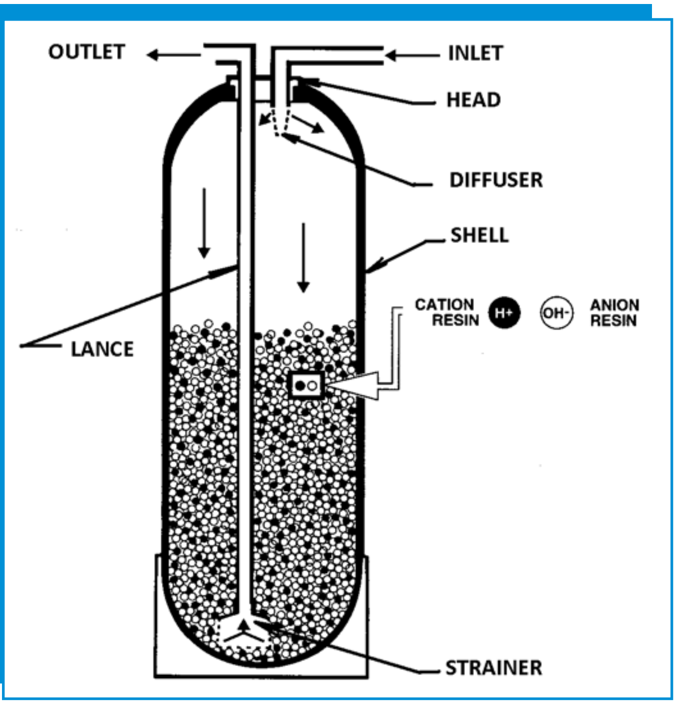

Fig #2b: Cross section of fiberglass resin tank courtesy of ABA Water Systems

incoming water stream over a wide area of the resin for maximum resin life. Without the diffuser, the water stream would likely make a channel in the resin bed, shortening its useful life.

- Mixed Bed of Resin
- Lance – The lance is basically a pipe which connects to the head and reaches down through the resin bed to collect the treated water once it has passed through the resin.
- Strainer – Mounted to the bottom of the lance, the strainer keeps the resin beads from exiting the tank along with the treated water.

- Resin Bag Systems – The typical resin bag system consists of the following components: ***(Fig# 3a,3b,3c)***
  - Housing – Made of stainless steel contains the bag and supports all the other system components
  - Cover – Also made of stainless steel, supports the diffuser and contains the inlet connection
  - Ring & Seal – Seals the cover to the housing
  - Pre-Filter – 5 micron filter that removes any solid particles that could contaminate the resin
  - Resin Bag – Cloth bag containing the mixed bed resin
  - Bottom Grid – Stainless steel component that supports the bag, directs water flow out of bag to prevent channeling, and provides for a free space underneath it that allows for the collection of the treated outlet water

Environmental Responsibility

Virgin (new) deionizing resin is essentially a neutral and harmless material. However, exhausted deionizing resin that is loaded with contaminants removed from the water in your machine cannot be safely or legally disposed in the trash. Please remember this most important point: You are ultimately responsible for the proper disposal of your resin or its treatment by-products forever. Your liability is unlimited by either dollar amount or time, even if it is your vendor that violates the law.

The logical and ecological solution to this problem is to recycle, or regenerate exhausted deionizing resin. Resin regeneration, if it is done in accordance with all EPA regulations, has a minimal effect upon the environment. In addition, regenerating deionizing resin is much less costly than purchasing virgin resin.

There are those that insist that virgin resin gives purer outlet water, has greater capacity, and has better pH control than regenerated resin. Let's examine each of these claims:

- Water Quality – Water quality is directly related to the number of active ionic sites imparted to each bead as a result of the chemical processing of the resin beads. Since the process of regeneration is similar to that used in making new resin, the care taken in the processing will have a direct effect on the water quality produced by either virgin or regenerated resin. In fact, some highly regarded domestic virgin resin suppliers purchase low quality imported virgin resin and then regenerate it to bring it up to USA standards. Thus, the virgin resin you purchase may already have been regenerated once, but in reality it makes no difference.
- Capacity - The argument presented previously applies here also.
- pH – The effects of pH on resin system outlet water are strictly related to the care taken in the rinsing procedures utilized after the chemical processing of the resin beads in either the virgin resin or regenerated resin manufacturing processes.

If you are utilizing a top quality regeneration house, the virgin vs regenerated argument doesn't hold up.

TCLP Testing

Although most exhausted resin is not considered hazardous waste, depending upon what you're cutting it could be. If your resin is determined to be hazardous waste, that determination will have substantial ramifications on the methods and costs associated with shipping and processing it.

A TCLP test (Toxicity Characteristic Leeching Procedure) will test your resin for the presence of any of the eight heavy metals that, depending on their concentration, might cause your resin to be characterized as being hazardous waste:

- Barium
- Cadmium
- Chrome
- Lead
- Mercury
- Selenium
- Silver

Fig #3a: Dayton style bag housing

Fig #3b: Ebbco style bag housing courtesy of Ebbco

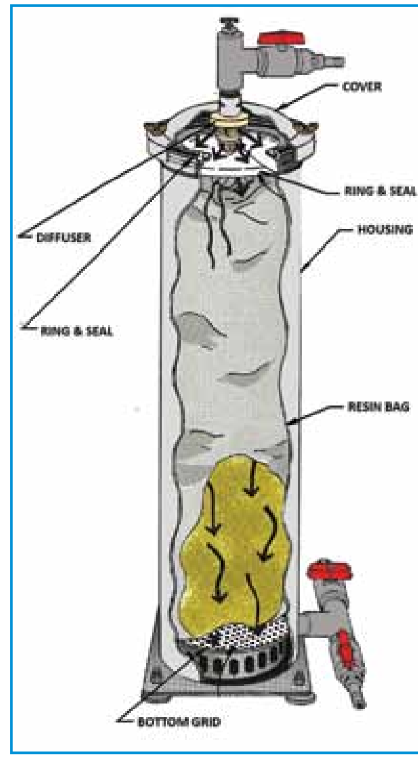

Fig #3c: Cross section of Ebbco style bag housing

This test should be performed the first time you send out resin for regeneration and then annually thereafter.

The test costs between $400 and $500, but it is a worthwhile investment to avoid any ugly and costly surprises.

Regeneration

Due to the overwhelming environmental and economic advantages of using regenerated resin compared to virgin resin, we will now examine the regeneration process in detail.
First, we'll look at the process for regenerating a mixed bed tank: ***(See Fig# 4a)***

- Evacuate Tank – The spent resin is evacuated from most tanks without removing the head by floating it out with water and suction either through the inlet port or a special access port in the head.
- Backwash – The spent resin is then washed . The backwash removes any particulate contamination that may have accumulated on the resin beads. Resin beads normally undergo some wear and tear during use and can break apart. These broken beads are also removed from the batch during the backwash.
- Separation - Since anion and cation resins have different densities and colors, they can be readily separated by loading the exhausted mixed bed resin in a vertical tank with a clear window on the side and flooding the tank

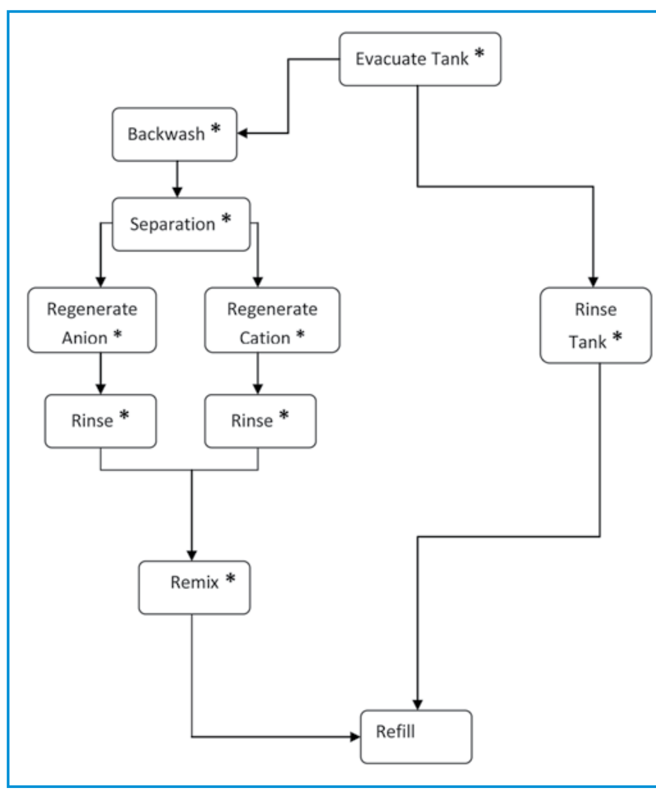

Fig #4a Tank regeneration process diagram

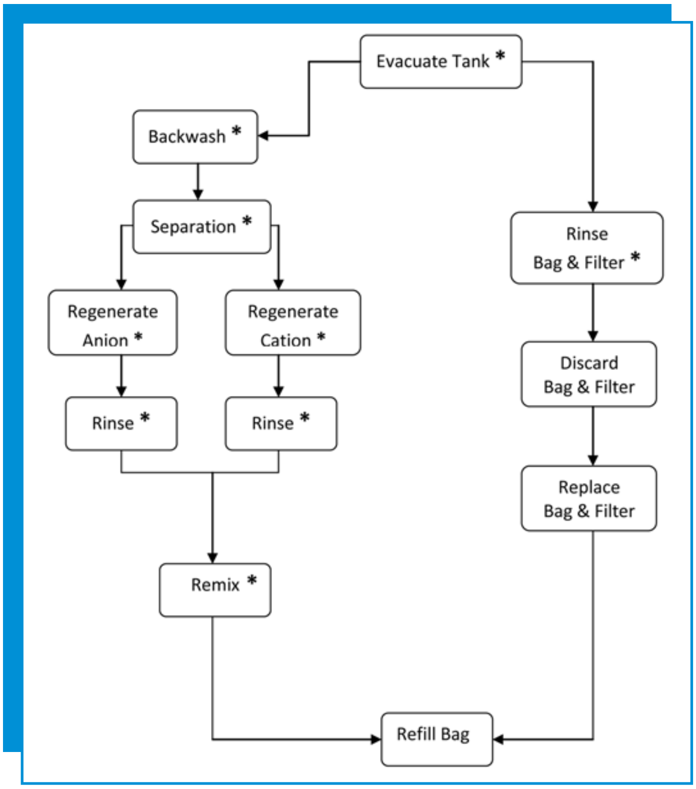

Fig #4b Bag regeneration process diagram

Fig #5
Regeneration cell courtesy of Nationwide DI Water Solutions

- *A: Backwash and separation tank*
- *B: Anion regeneration and rinse tank*
- *C: Cation regeneration and rinse tank*
- *D: Mixing and rinse tank*
- *E: Rinse water storage tank*

with water. The less dense beads will float to the top and there will be a clearly visible separation line between the anion and cation beads. This allows each type of resin to be drawn off and sent to separate subsequent regeneration processes.

- Regeneration -
  - The cation beads are loaded into a tank that is filled with muriatic acid, which strips the contaminant positive ions from the beads and replaces them with with H+ ions.
  - The anion beads are loaded into a tank that is filled with caustic soda (typically H_2SO_4) , which strips the contaminant negative ions from the beads and replaces them with with OH- ions.
- Rinse – The resin beads are subjected to one or more rinse cycles to remove any trace of acid, caustic, or other contamination
- Remix – The anion and cation beads are then thoroughly mixed to the proper 60:40 blending ratio. Due to the normal fallout of beads associated with the regeneration process, make-up resin is also added to the mixture at this step. This step often includes another rinse cycle.
- Rinse Tank – While the resin is being regenerated, the tank itself is thoroughly washed.
- Refill – The tank is then loaded with the regenerated resin with a vacuum process.

Next, we'll look at the process for regenerating a mixed bed bag. ***(See Fig# 4b)*** Since many of the operations for regenerating a bag are identical to those used in regenerating a tank, we'll only list those that are unique to the bag regeneration process:

Fig #6
Waste water treatment system courtesy of ABA Water Systems

Fig #7
Safety screen

- Empty Bag – The bag is opened and the contents dumped out.
- Rinse Bag & Filter – The bag and filter are rinsed to remove any contaminants
- Discard Bag & Filter – The rinsed elements are now disposed as trash
- Replace Bag & Filter – Most reputable regenerators supply both a new bag and filter
- Refill Bag – The new bag is refilled with the regenerated resin

Fig# 5 depicts a state-of-the-art regeneration setup and is annotated to identify the major components.

Waste Water Treatment

You may have noticed that in the regeneration process diagrams there is an asterisk (*) in many of the flow chart process step boxes. The asterisk signifies that the process step so marked produces waste water that must be treated. In fact, the water used in any process that comes in contact with resin or a resin system component is contaminated and must be treated prior to being discharged into the sewer system. For example, even the water used to rinse out the tank or bag must be treated. Some low budget “refill operations” buy regenerated resin in bulk and refill tanks and bags in branch facility, disposing untreated water into the sewer system. This is illegal. It is a little known fact that reputable resin regenerators spend more money treating their waste water than regenerating the resin! The water treatment facilities often take up the majority of the floor space in the plant.
(see Fig# 6)

The following is a typical waste water treatment regimen:
- Add neutralizing chemicals to the waste water to precipitate ions out as solids
- Add flocculent to the waste water to facilitate settling separation of the solids
- Load treated water into settling tank
- Draw off water from settling tank and decant
- Filter water through filter plates
- Adjust Ph
- Discharge (Continuously monitored)

The filter plates are further processed as follows:
- The filter plates are compressed in a special press for form a “cake”
- The “cake” is scraped from the filter plates
- The “cake” is sent to a licensed, lined, covered sanitary land fill as industrial metal bearing waste.

As is clearly evident from the above wastewater process treatment schedule, the integrity of your regenerator is your protection from being indirectly liable for the improper disposal of the by-products that come off the resin beads and the processes water.

For those of you who think that just sending out your resin to a vendor limits your liability, please read the following:

Fig #8 Pre-filter

In the eighties, my company utilized 1-1-1 trichloroethane as a degreaser to clean the dielectric oil from parts after EDMing. We purchased this product from a reputable dealer of a national chemical company, who also handled the recycling of this product for us. They relied upon a recycling company that was fully permitted by both the state of Massachusetts and the Federal Government. Unfortunately, the recycling company disposed of the tailings from the distillation process by dumping it into wetlands between two major rivers. The recycling company ultimately went bankrupt, leaving a $24,000,000 Superfund reclamation project in its wake. The customers who sent materials to this site to be recycled were held financially responsible for the entire clean-up cost.

Needless-to-say, it is essential that you perform thorough due-diligence before sending out resin for either regeneration or disposal. Such due diligence might include:

- Examination of permits by state EPA and local wastewater treatment authorities
- Thorough review of processes and procedures
- On-site visit (if possible) or careful review of photographs of facilities and equipment

Resin Tips

Prior to closing this admittedly lengthy treatise, let me leave you with a few tips that may save you time and money:

- Regularly clean the conductivity probe on your wire machines. The best resin system is useless if the conductivity control system receives bad information from its sensor.
- Install a safety screen on the outlet side of your resin system to preclude stray resin beads from contaminating you machine in the event of an accident. ***(See Fig #7)***
- For tank systems, install a pre-filter on the resin system inlet line. This will substantially lengthen your resin life. ***(See Fig# 8)***
- Don't scrimp on your filters. A blown filter or high micron rating turns your resin system into an expensive filter.
- Don't let cleaning chemicals get into your dielectric system. They will drastically shorten resin life and possibly destroy the resin.
- For additional tips concerning resin systems, please visit edmtodaymagazine.com and download the May-June, 2006 article from our archives.

Conclusion

The resin system of a Wire EDM is one of those "out of sight, out of mind" things. A proper understanding of the basics of the ion exchange process, the regeneration process, and the potential environmental liabilities will help maintain EDM consistency and keep you on the right side of the law.

Acknowledgements

I'd like to thank Neil Weaver, owner of ABA Water Systems, for his gracious hospitality in hosting my visit to his facility and for providing valuable insights into the regeneration process.

I'd also like to thank Dr. Duane Nowlin for his invaluable assistance in patiently explaining the details of both the ion exchange and regeneration processes.

Roger Kern