INTERPRETATION
OF
RESIN ANALYSIS

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Interpretation of Resin Analysis

Introduction

The purpose of this discussion is to describe the various lab tests that can be performed with ion exchange resins and what the results mean in terms of field performance. The intent is to aid users of ion exchange resins to decide which tests they should specify to be performed and how to interpret the results that are reported. This discussion is not intended to describe how lab procedures should be performed, except in a general way. The ASTM standards, Section II are an excellent reference for specific lab procedures. Other laboratory reference guides have also been published by Dow, R&H and other resin manufacturers.

What are the Tests?

We have divided the tests into three categories: Routine, Semi-Routine and Specialty - based on what most labs perform as a quality check for new resins and on the common tests that most labs perform for used resins. The specialty tests generally take more time and effort and increase the cost of the analysis, therefore, they are not commonly performed unless there is a specific need to do so.

As with any attempt to separate data into somewhat subjective categories, the author's opinions have no doubt caused some bias. Experienced readers should feel free to reorganize to suit themselves.

Routine Tests

Routine tests always include determining a resin's total capacity and moisture content. There is almost always a visual inspection by microscope and often a measurement of the particle size distribution. For strong base anion resins, there is almost always a test for salt splitting capacity as well as for total capacity.

Brief Description of Routine Tests

Total Capacity

A known volume (or weight) of resin is placed in a column. An excess of chemical solution is passed through the resin to be certain it is in a known ionic form. The known ions are then eluted from the resin using an excess of a (different) regenerant chemical solution. The concentration of the known ion eluted (or exchanged) is determined quantitatively. The capacity is generally reported as milli equivalents capacity per milliliter (or gram) of resin, based on a reference ionic form.

Brief Description of Routine Tests

Routine Tests

Total Capacity
Salt Splitting Capacity
Moisture Content
Visual Inspection (% whole bead)

Semi -Routine Tests

Cation/Anion Ratio (for mixed beds)
Ionic Form as Received
Inorganic Impurity Levels
Iron
Sodium
Others
Screen Size Distribution
Water Soluble Organics
Kinetic Tests
Bead Crush Strength (Friability)
Rinse Requirement

Special Tests

Column Capacity
Specific Gravity
% Volume Change
Osmotic Stress Test
Oxidative Stability
Ash Analysis
Resin Cleaning Tests
Identification of Foulants

Salt Splitting Capacity

The difference between salt splitting and total capacity is determined by the choice of regenerant used. Total capacity tests are generally performed with acids (NaCl, $NaNO_3$ or HCl) or bases such as (NaOH) while salt splitting capacity tests are performed with neutral salts.

There are several different procedures that have been published for each type of capacity test. Differences in procedures cause small differences in the results that are reported. However, the biggest differences are caused by the initial volume measurement of the resin sample.

For this reason, some labs prefer to report weight capacities as opposed to volume capacities. Even wet weight capacities can cause variations in results, and therefore, a few labs insist on reporting dry weight capacities.

Moisture Content (also called water retention or percent solids)

This test is performed by weighing the moist resin and then drying to constant weight in an oven (usually at l05^{o}C). The only variation is in how a lab removes surface moisture from the wet resin prior to drying in an oven. The method of blotting the surface moisture can cause an error lowering the reported moisture while vacuum filtration can cause an error increasing the reported moisture.

Visual Inspection

The general method is to examine the resin under a microscope at 20-40X magnification. The lab reports a somewhat subjective evaluation of the number of cracked or broken beads. This can be reported as a percentage of the total number of beads or as a percentage of the total volume of resin. Some labs use weighing techniques such as counting fragments and then dividing by an assumed number of fragments per whole bead or by not counting fragments smaller than a certain size. There is a considerable difference among the methods used. Labs seldom volunteer how the percentage they are reporting was calculated.

The visual examination usually includes a qualitative estimate of the amount of physical contaminants and debris present in the sample and may also include a qualitative assessment of biological fouling or other foulants coating the resin beads.

Brief Description of Semi-Routine Tests

Semi routine tests are divided into two categories according to those most commonly performed for new resins and those performed for used resins.

New Resin

When there are special requirements for new resin, a number of extra tests can be conducted to verify that the resin meets those requirements.

Screen Size Distribution

This test can be performed by a particle counter or by mechanical sieves through which the resin is passed. The results can be reported in a variety of formats, either in actual size (usually reported as microns) or in mesh size (usually reported as a plus or minus a particular sieve size). The results are usually reported as volume percentages within a particular size range.

Friability (crush strength)

This test measures how many grams of force are necessary to shatter a resin bead, usually reported as an average from a random sample of whole perfect beads within a particular size range. Friability can vary significantly with the ionic form of a resin, particularly those resins that undergo a significant volume change from one ionic form to another.

Organic Extractables

This test is generally performed by heating a sample of resin in deionized water for a specific amount of time (l6 hours @ 65^{o}C is common) and then either determining the TOC of the water or removing the resin, evaporating the water and weighing the residue. Results can be reported in a variety of formats, most commonly as weight of the extractable per volume (or weight) of resin.

Inorganic Impurities

There are two approaches to measuring the level of inorganic impurities contained in the resin. For volatile impurities (such as sulfates, chlorides, carbonates, ammonia, etc.) the usual method is to elute the contaminants, measure the concentration in the spent regenerant and then quantify the concentration as a percentage of the total exchange sites.

For metallic contaminants, the usual procedure is to ash the resin, dissolve the residue, then measure the concentration of the contaminants, reporting the concentration as parts per million (lbs. impurity/million lbs. of resin).

Used Resin

For used resin, a variety of other tests are performed to evaluate how the resin should perform in the equipment.

Rinse Requirement

This test is usually performed with the resin after regeneration with various chemical solutions.

The purpose is to determine how easily the chemical solution can be removed from the resin and is generally performed with deionized water. The result is reported in bed volumes rinse to a certain end point (or as gallons per cubic foot of resin). The result depends strongly on the tests conditions (such as flow rate, temperature, bed height, etc.) and is usually referenced against new resin or against a known resin performance.

Kinetic Tests

These tests are similar to the test for rinse requirement but are performed using a rinse solution of known composition. The flow rate is varied to determine the flow sensitivity of the resin. There are a variety of different procedures in use and the results are generally compared against a typical value for new, good quality resin as a standard.

Ionic Form (as received)

This test is similar to the total (or salt splitting) capacity tests except that the elution is performed without first converting the resin to the reference ionic form. The spent regenerant may be further analyzed for impurities. The results are generally reported as a percentage of the resin's capacity.

Percentage Ratio (of mixed resins)

This test is performed for beds of mixed resin, usually cation and anion but sometimes for other mixtures.

The general procedure is to separate the resins hydraulically (or by means of density differences), then measure the volume of each component. The result is generally reported as a volume percentage of each species but may also be reported as a percentage of total ion exchange sites.

Brief Description of Specialty Tests

A number of tests can be performed on new resin in order to predict how the resin will perform under unusual operating conditions, or to identify specific contaminants that might be present.

Column Capacity

This test is performed by exhausting a resin column with a solution of specific composition to a specific endpoint. The end user generally defines the solution and the endpoint. In some cases, the column is regenerated and exhausted several times in order to determine the operating capacity. The results are generally reported as bed volumes of through-put (or gallons per cubic foot).

Oxidative Stability

This test is performed by soaking the resin in a solution with a known concentration of a user specified oxidizing agent, sometimes at elevated temperatures. The result is reported as capacity remaining (or lost) over a period of time. In many cases, the moisture content of the resin before and after exposure to the oxidant is also reported.

Osmotic Shock Test

A sample of the resin is subjected to acidic and then basic conditions over and over (hundreds of times) to determine its physical stability. The test should include rinsing with deionized water in between each cycle as the object is to create an osmotic pressure difference at the surface of the resin beads. The result is reported as the change in the percentage of broken resin beads over a certain number of cycles (often 300).

Apparent Density

This test is performed by measuring the volume of a known weight of resin. The result is reported as grams per milliliter (or pounds per cubic foot). The volume measurement procedure can be performed by tapping the resin to minimum volume or by backwashing and allowing the resin to gently settle. Tapped volumes are generally used for capacity determinations, whereas backwashed and settled volumes are often used for shipping weights.

Void Volume

Void volumes are calculated from the volume of water that can be drained from a known volume of resin. Void volumes vary significantly based on backwashed and settled vs. tapped vs. mixed volumes of resin.

Specific Gravity

This test can be performed by placing a sample of resin in water, (or other solvent), gradually increasing the solution concentration until the resin begins to float. Another method is to calculate "true density" from the apparent density and the void volume.

Percent Volume Change

This test is performed by measuring the volume of a sample of resin in a particular ionic form, then converting the resin to some other form and again measuring the volume.

Ash Analysis

The resin is burned, the ashes are redissolved and then analyzed for metallic impurities. This may be performed qualitatively or quantitatively. Another similar method used X-ray difraction technology to quantitatively measure metal concentrations in a resin sample. X-ray difraction is not very precise, but is a fast way to determine high levels of metallic impurities.

Cleaning Tests

Cleaning tests are performed on fouled resin samples to determine if a specific cleaning procedure will be effective to restore the performance of the resin. These tests are usually user defined based on the type of foulant suspected (or identified). The result (usually column capacity or rinse requirement) is compared to a reference sample of fouled resin that was not cleaned, or to the customer's requirements (expectations) for the system.

Identification of Foulants

These tests can involve many types of analyses depending on the type of foulant suspected. They generally involve some type of extraction to separate the foulant from the resin, followed by various qualitative and/or quantitative analysis. Identification of biofoulants may also involve culture tests in various growth media. Without any clues to a foulant's origin, these tests can be very arduous.

What Do The Tests Mean?

From the enduser's standpoint, the results of a resin analysis may not be of much help. Lab analyses generally are reported in unfamiliar terms. There is often no reference point against which to compare the values given. Another problem with interpretation of a lab report is that there are differences in the way that various labs perform a particular test, resulting in significant variations in the values reported. For instance, a resin manufacturer will probably report a resin's capacity without first cycling the resin. In the very first cycle, many resins undergo an irreversible swelling that significantly reduces their volume capacity. Some resins (almost notably) lose a small but significant portion of their capacity during the very first cycle. An inexperienced consumer, who is comparing their recently installed resin against the manufacturer's standard for new resin might be led to believe that the resin has been significantly damaged when, in fact, the difference is due to the method of testing. Resin manufacturers set their published specifications somewhat looser than their new resins typically meet, thus a resin that is significantly damaged may still meet new resin specifications.

There are many potential pitfalls in the interpretation of a resin analysis. For critical applications, it is advisable to obtain the results of the resin manufacturer's tests for that resin and then retest the resin shortly after the first use. The test results can then be used in the future as a reference point against which the later resin tests results can be compared.

Many applications are not so critical and it is not necessary to spend a lot of time and effort testing and retesting the resin. After all, the system itself will often reflect the condition of the resin. It is still a good idea to obtain a copy of the new resin's analysis, because sooner or later resins do wear out and it is helpful to have the original specs to compare against when trying to justify the cost of new resin to management.

Capacity Tests

All resin manufacturers will provide the QC analysis of their resin (although it may be necessary to be persistent to obtain a copy of it). Strong base anion resins can have a substantial difference between total and salt splitting capacities. This difference can be present even in new resins. The salt splitting capacity is by far the most important in many demineralizing applications, particularly those requiring low silica leakage and high effluent purity. Type II strong base anion resins and Type I acrylic strong base anion resins lose salt splitting capacity much faster than Type I styrenic strong base anion resins and are prone to significant differences between salt splitting and total capacities even when new. For high purity and/or low silica applications that use these anion resins, it is important to verify that the salt splitting and total capacities of new resins are essentially equal and that the difference in used resins has not become unacceptably large. There are no absolute rules concerning a maximum allowable difference. However, when the salt splitting capacity is half the total capacity, the resin will most likely not perform well. A l0-25% difference is the point at which performance deterioration begins to occur in high purity/critical applications.

Strong base anion resins are chemically unstable and degrade over time, even when not in use. The other types of resin, strong cation, weak cation and weak anion are much more stable and tend to lose capacity only when chemically degraded or when the ion exchange sites become fouled.

Differences between total and salt splitting capacities are of value with weak base anion and weak acid cation resins only in applications where pH is important. For strong acid cation resin, there is almost never a difference between total and salt splitting capacity.

In weakly basic anion resins, the amount of salt splitting capacity affects the effluent pH, the rinse requirement and effluent conductivity. A weakly basic anion resin that has no salt splitting capacity will have very poor rinse characteristics and will produce a low pH.

With increasing salt splitting capacity comes improved rinse, high pH and better quality, until at approximately 50% salt splitting capacity, the resin begins to function like a strong base anion resin.

Weakly acidic cation resins behave in a similar fashion to weakly basic resins with respect to salt splitting capacity except that the effluent pH decreases with increasing salt splitting capacity. Since weak acid cation resins are frequently used as dealkalizers, salt splitting capacity is not necessarily a desirable characteristic.

In certain cases where fouled resin is analyzed, it may be useful to look for unwanted capacity. For instance, organically fouled strong base anion resins can have a significant amount of total cationic capacity caused by the organic acids. This unwanted capacity causes the long rinses that plague organically fouled anion exchangers.

Salt splitting capacity that is blocked by organic acids can still show up as total capacity. The difference in salt splitting capacity before and after cleaning gives an indication of the severity of the organic fouling.
Total and salt splitting capacity tests are used to compare various new resins against the manufacturer's standard and to compare various resin brands against one another. They are also used to judge a used resin's rate of deterioration and to determine when resin replacement is advisable.

The difference in total capacities does not always translate into operating capacity differences. The way in which the resin is used has a much larger influence on operating capacity than does the total capacity. However, all things considered, it is safe to say that if total capacity falls below a certain value, the operating capacity will be reduced.

For new resins, the total capacity can be used to judge if a resin has been properly manufactured and has not been damaged prior to use. However, in most cases, the lab analysis will not include such tests unless specifically requested.

Table of Capacity Comparisons

For Common Types of Strong Acid Cation Exchangers
Based on ResinTech Inc. Resins

	meq/mL	**Salt Splitting Capacity**	
Sodium Form	**Minimum Spec. ***	**Typical New ***	**Grounds for Replacement**
8% Gel	1.95	2.05+	1.6 25-50% loss
10% Gel	2.2	2.25+	1.7 25-50% loss
12% Macropore	1.7	1.8+	Physical Deterioration
20% Macropore	1.7	1.7+	Physical Deterioration

Note: Total capacities are not usually performed for strong cation resins but should be the same.

For Common Types of Weak Acid Cation Exchangers
Based on ResinTech Inc. Resins

meq/mL Total Volume Capacity

Hydrogen Form	Minimum Spec. *	Typical New *	Grounds for Replacement
Gel	4.3+	4.4+	Physical Deterioration
Macropore	3.6	4.0	Physical Deterioration
Methacrylic	3.6	3.9	Physical Deterioration

Note: Salt splitting capacities are not usually performed for a weak cation resin, but should be less than l0% of the total capacity.

Sodium form capacities are l/2 to 2/3 of hydrogen form capacities due to the volume change.

* These are for ResinTech products. Other manufacturers' products may vary.

For Common Types of Strong Base Anion Exchangers
Based on ResinTech Inc. Resins

meq/mL Total Volume Capacity

Chloride Form	Minimum Spec. *	Typical New *	Typical After Cycling
Porous Gel Type I	1.25	1.3+	1.15
Gel Type I	1.45	1.5+	1.3
Gel Type II	1.45	1.5+	1.3
Macroporous Type I	1.15	1.15 - 1.2	1.1
Acrylic Gel	1.2	1.25 - 1.3	1.1

Note: New strong anion base resins should have salt splitting capacities that are the same as their total capacities.

For Common Types of Weak Base Anion Exchangers
Based on ResinTech Inc. Resins

meq/mL Total Volume Capacity

Free Base Form	Minimum Spec. *	Typical New *	Typical After Cycling
Epoxy Polyamine	2.6	2.6 - 3.0	2.4 - 3.0
Gel Tertiary Acrylic	1.6	1.6 - 1.7	1.5-1.6
Macro Tertiary Styrene	1.6	1.7	1.6 - 1.7

Note: New weak base anion resins with styrenic or epoxy matrix generally have salt splitting capacities equal to 5-10% of their total capacities.

Moisture Content

Moisture content of new resins varies according to the type of resin, degree of crosslinking, functionality and ionic form. Resin manufacturers allow themselves a fairly wide range in their stated moistures for new resins. Furthermore, there are significant differences in reported moistures based on how a particular lab performs the test.

For this reason, moisture content alone is not of great help in deciding if a particular resin is good or bad. However, some general comments can be made about new and used resins.

For new gel type strong acid cation resins of good quality, the relative moisture content directly reflects the percent crosslinking and the capacity. The lower the moisture, the higher the crosslinking and the higher the capacity (up to about l2% cross linkage down to about 35% moisture). Many labs use the moisture content of new resins to verify that capacity tests were performed correctly.

In general, for all resins, lower moistures mean improved resistance to oxidation, higher friability and higher volume capacity, but poorer organic fouling resistance, worse osmotic shock resistance, poorer kinetics and worse regeneration efficiency.

When comparing the moisture content of used resins, it is absolutely imperative to compare the moisture content of the resin when new (but after a few cycles) and that both tests be performed in the same way. Otherwise the variables are larger than any real differences. In general, resins that have been oxidized have increased moisture while resins that are fouled have decreased moisture.

Visual Inspection

Although somewhat subjective, a visual inspection under 20-40X magnification is a very valuable tool for judging a resin. In my experience I have found that "while you may not be able to tell if a resin is good just by looking at it, you can sure tell if it is bad!"

For new resins, the resin sample really should be all one kind of material. New resins should also be clean, free of foreign material and not unusually large or small in bead size. Some resin manufacturers "blend off" batches of resin that do not meet their specs into batches of resin that exceed their specs. While not illegal, this practice may cause field performance problems. The two areas where blending off most frequently occurs are with broken beads mixed into a batch of whole bead resin and with low capacity resin mixed into a batch of higher capacity resin. Evidence of blending can often be seen when examining the resin visually.

For used resin, the visual inspection can identify the degree of physical damage (cracked and broken beads). It can also identify the presence of physical foulants such as dirt, organic matter and biological growths. Some types of chemical foulants can also be seen, especially when they have precipitated on the surface of the resin.

All in all, the visual examination is useful and is easy to perform even in the field.

Screen Size Distribution

Some resin manufacturers would have us believe that the screen size distribution of a resin is its most important attribute. In most cases, however, the distribution is relatively unimportant.

Resin beads that are larger than 16 mesh tend to fracture easier than smaller beads. Beads smaller than 50 mesh tend to cause problems with high pressure loss and are easily backwashed out of a resin bed. This is why the default standard for mesh size distribution is l6-50 mesh.

When looking at a screen distribution, it is usually sufficient to just look at the amount of big and small beads. However, some applications (such as mixed beds, very high flow rate systems and chromatographic resin columns) have specific requirements for size distribution. In these applications, the exact size distribution and range of sizes may be a requirement. Some resin manufacturers “cut out” the center portion of a normal distribution leaving only the big and small beads. This practice is probably harmless in most applications, but can adversely affect performance.

For used resins that originally had a screen size distribution, an additional screen size distribution has little value. The visual examination is a much better way to judge a used resin’s physical condition.

Friability (crush strength)

Resins with less than l00 grams crush strength fall apart easily and are probably not of use in most ion exchange applications.

Crush strengths above 200 grams are generally satisfactory for almost all ion exchange applications. Crush strengths above 500 grams per bead are sometimes necessary for condensate polishing and other high flow rate applications. The hardest of ion exchange resins have crush strengths in excess of 1,000 grams per bead.

Friability is not a good predictor of physical toughness or resistance to fracture in operating systems. A resin that is very elastic can distort without breaking. There are examples of installations where a resin with l00 gram crush strength outlasted a resin with 600 gram crush strength.

Organic Extractables

The results from this type of test vary according to the method, time, temperature, and volume of solution used in the extraction. Therefore, the results are relative and somewhat subjective. Lower levels of extractables reflect a cleaner product. Levels below 250 milligrams extracted per kilogram of resin generally indicate a very clean product.

This test is most useful for new resins, particularly those used for single use, nonregenerable, high purity applications.
Extractables from used resins are seldom of help except to quantify an extent of fouling reflected by changes in other test results.

Rinse Requirement

This is a very useful test for both new and used resins (particularly strong base anion resins).

Rinse requirements generally increase as a resin becomes fouled or oxidized. A new resin with poor rinse characteristics is probably not suitable for a high purity application.

Rinse requirements have a direct effect on the economics of operating an ion exchange plant. In some cases, a particular resin may have such a poor rinse characteristic that it will not reach the ultimate water quality needed for a particular application, and therefore, cannot be used. Rinse requirements of anion resins almost always increase with a resin's age.

Fast Rinse Characteristics
For the Most Common Types of Cation Exchangers

	Typical Design Values for Multiple Bed Service	Typical Rinse Volumes for Non-fouled Resin to Reach Various Qualities. Includes 10 gals. per cubic foot Displacement Rinse		
Cation Exchangers	**Gals./cu.ft.**	**17 PPM Gals./cu.ft.**	**1 PPM Gals./cu.ft.**	**0.1 PPM Gals./cu.ft.**
Strongly Basic NEW	50	10 - 15	15 - 25	25 - 50
Strongly Acidic USED (Approx. 1 yr.)		10 - 20	15 - 25	30 - 100
Weakly Acidic NEW	50	10 - 15	15 - 25	25 - 50
Weakly Acidic USED (Approx. 1 yr.)	NA	10 - 20	20 - 30	30 - 100

Fast Rinse Characteristics
For the Most Common Types of Anion Exchangers

	Typical Design Values for Multiple Bed Service	Typical Rinse Volumes for Non-fouled Resin to Reach Various Quantities. Includes 10 gals. per cubic foot Displacement Rinse		
Anion Exchangers	**Gals./cu.ft.**	**17 PPM Gals./cu.ft.**	**1 PPM Gals./cu.ft.**	**0.1 PPM Gals./cu.ft.**
Strongly Basic NEW (Type I or Type II)	75	10 - 15	25 - 50	25 - 50
Strongly Acidic USED (Approx. 1 yr.)				
Type I	NA	15 - 20	30 - 50	50 - 100
Type II	NA	15 - 20	30 - 75	50 - 200
Weakly Acidic NEW	75	15 - 20	30 - 75	50 - 150
Weakly Acidic USED (Approx. 1 yr.)	NA	15 - 20	30 - 75	50 - 200

Kinetic Tests

These tests are useful for new resins that will be used in high flow rate/high purity applications. The best resins show very little sensitivity to the effect of increasing flow rate or increasing ionic concentration.

Resins that are kinetically impaired perform worse at high flows than low flows, worse at high inlet concentrations than at low concentrations.

Ideally, the kinetic test is performed under a similar condition to those used in the particular system that the resin is being tested for. The test then demonstrates that the resin is suitable for use in that system.

Organically and physically fouled resins can show reverse flow sensitivity where the quality improves as the flow increases. This phenomenon is caused by regenerant chemicals failing to rinse out of the resin bed. Strong base anion resins that have a large difference between salt splitting and total capacity are particularly prone to this problem.

Ionic Form (as received)

For new resins it is important to know what ionic form the resin is in as this determines storage and handling requirements as well as conditioning and/or regeneration requirements prior to use. For resins purchased in the regenerated form, the degree of regeneration into the desired chemical form directly translates into throughput capacity and is therefore a significant datum to use when judging if a resin is suitable for use in a system.

For used resins, the percent regeneration is useful to judge the overall efficiency of the system and can be used as an aid to troubleshooting.

Degree of Regeneration Level

	Typical Values for New and Unused Resins *	Typical Values for Core Samples from Used Resins Immediately After Field Regeneration (equivalent to air mixing the bed after regeneration)		
Common Types of Cation Exchangers	**% of Total Cap.**	**Poor % of Total Cap**	**Typical % of Total Cap.**	**Well % of Total Cap.**
Strongly Acidic Sodium Form (softening)	100	15 - 35	55 - 85	85+
Strongly Acidic Hydrogen Form (demineralization)		15 - 35	55 - 85	85+
General	95+			
Nuclear	98+			
Semiconductor	99+			
Weakly Acidic				
Sodium Form	98+	<80*	90+	98+
Hydrogen Form	98+	<80*	90+	98+

	Typical Values for New and Unused Resins *	Typical Values for Core Samples from Used Resins Immediately After Field Regeneration (equivalent to air mixing the bed after regeneration)		
Common Types of Anion Exchangers	**% of Total Cap.**	**Poor % of Total Cap**	**Typical % of Total Cap.**	**Well % of Total Cap.**
Strongly Basic - Hydroxide Form				
Type I - General	85+	<25	33-65	70+
Type I - Nuclear	90+	N/A	N/A	N/A
Type I - Semiconductor	95+			
Type II - General	85+	<90	90+	95+
Type II - Nuclear	90+			
Type II - Semiconductor	N/A	N/A	N/A	N/A
Strongly Basic - Chloride Form	98 +	33	75+	90+
Weakly Basic - Regenerated with Sodium Hydroxide	Free Base 100%	<90*	92+	98+

* Weakly acidic and weakly basic resins regenerated at "starvation" levels may be lower. These values are typical of ResinTech resins. Nuclear and semiconductor grades often include specified maximums for various contaminants as well as minimums for percent conversion to the desired ionic form.

<u>Mixed Resin Percentage Ratio</u>

This test is used with new resins to determine if the manufacturer provided the specified ratio and if the ratio is the same throughout a batch of mixed resin.

For used mixed resins, the relative ratio is important to verify that no change has occurred over time.

Mixed beds with in-place regeneration and fixed collectors are designed for a specific ratio and cannot tolerate a large variation from the design ratio.

If the resin ratios were chosen to optimize performance for a particular influent ion balance, changing the ratio will result in less than optimum performance for those conditions.

Multiple mixed beds that share a common external regeneration system are particularly prone to variations in ratio.

Column Capacity

These tests have to be interpreted on a case-by-case basis, as they are meaningless except within the context of the specifications at which they were run. Column tests that are only operated through one exhaustion cycle give misleading results and do not reflect how a resin could be expected to perform after several cycles. Lab columns are much smaller than most equipment systems and, therefore, provide some distortion in the results. Still, column tests are useful for testing a resin's applicability to special applications where other performance data is not available.

Oxidative Stability

This special test is of value to compare various resins that will be used under oxidatively challenging conditions. The oxidative stability of most common resin types is well established and published (although perhaps not easily located).

Osmotic Shock Test

This test is seldom performed due to its time consuming nature and because it does not correlate well with resin life expectancy.

Apparent Density

This test is used to establish the shipping weight of new resins and is of little use except for this purpose.

Specific Gravity

This test is useful for new resins to estimate backwash expansion and for mixed resins to estimate ease of separability.

Void Volume

This test is so variable that it is of little practical value. Void volumes of less than 30% generally reflect a potential problem with high differential pressure during service.

Percent Volume Change

The results of this test are very helpful to determine the tank size required to hold a certain amount of resin in its regenerated and exhausted forms. Some resins swell more than 15-20%. Special techniques may be required in the equipment design to accommodate the changes in resin volume.

The percentage of volume change characteristics of the more common ionic forms is available from resin manufacturers. The more unusual applications (particularly those involving liquids other than water) may require a special test to verify how much volume change occurs under unusual conditions.

Ash Analysis

Ash analysis is useful to verify metallic impurities in resins, particularly heavy metals that cannot be eluted from the resin by normal regeneration techniques.

Nuclear grade resin specifications often include requirements for the analysis of metal impurities such as copper and iron while ignoring impurities that might be left over from the manufacturing process (such as aluminum or zinc).

The total level of metallic impurities in a very clean, well regenerated resin sample will be less than 50 PPM.

For used resins, the ash analysis is used to verify the presence of metallic impurities that may be blocking ion exchange sites or precipitated inside the resin beads. These types of fouling cannot be proven by any of the other tests (although a decrease in moisture accompanying a decrease in capacity may arouse suspicions that metal fouling is present).

Cleaning Tests

As with column tests, cleaning tests are only relevant for a particular resin sample and set of cleaning procedures. It is safe to say that if a lab cleaning test fails to significantly improve a resin's performance, it is not worth performing that cleaning procedure on the equipment. Many cleaners do some damage to the resin and thus the potential harm can be compared against the benefit before selecting a particular cleaner to use. Laboratory cleaning tests can help to determine if field cleaning is economically justified. However, these tests are very time consuming and are generally not justified for small quantities of fouled resin.

Identification of Foulants

For common foulants such as iron, identification is fairly simple. However, identification of unusual foulants can be very time consuming. In most cases an investigation of the inlet water is a more effective approach than identification of a foulant on a resin. The ID of the foulant often helps to choose among potential cleaning procedures.

Closure

In rereading this discussion for use by Ultrapure Magazine, I see that I have left myself open to criticism by end users, resin testing labs and by resin manufacturers. I have a few words for each in anticipated rebuttal.

To End Users: Unless your application is very critical and/or you have many thousands invested in your ion exchange resins, a yearly routine health check is all you should be doing. If the resins' performance deteriorates gradually, you have the luxury of deciding the best time to replace the resin. If your resin suddenly fairs to perform and the problem is not readily apparent and easily remedied, buy new resin at once. You will most likely spend more trying to clean the resin than it is worth. Find the problem and fix it before ruining your new resin.

To Resin Testing Labs: We have an obligation to do a better job explaining our results. We also should be willing to spend a little extra time to offer our customers useful advice.

To Resin Manufacturers: Have you stopped making lousy resins yet? (I always wanted to say that).

What Tests Should You Specify?

Salt Splitting Capacity	**New**	**Used**
Weak Cation	2	3
Strong Cation	1	1
Weak Anion	2	3
Strong Anion	1	1

Total Capacity	**New**	**Used**
Weak Acid Cation	1	1
Strong Acid Cation	3	3
Weak Base Anion	1	1
Strong Base Anion	1	1

	New	**Used**
Moisture - All resins	1	1
Visual - All resins	1	1

	New	**Used**
Screen Size	2	3
Friability	2	3
Extractables	2	2
Inorganic Impurities	2	2

Rinse Requirement	**New**	**Used**
Weak Acid Cation	2	2
Strong Acid Cation	2	2
Weak Base Anion	2	1
Strong Base Anion	2	1

Kinetic Test	**2**	**2**
Ionic Form	2	1
Percentage Ratio of Mixed Resins	1	1

NOTE: Specialty tests should be specified only when they apply to a certain application.

Codes:

1 = Always very important
2 = Maybe - Relevant to special applications
3 = Seldom - Probably not worth the effort

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