

TECHNOLOGY REVIEW OF RESIN CLEANING PROCESSES

B&V PROJECT NO. 180448

PREPARED FOR

Recirculation Technologies, LLC.

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1.0 Executive Summary

Recirculation Technologies, LLC (RTI) retained Black & Veatch to perform an independent technology review of its ion exchange resin cleaning processes and the services it offers to industrial clients. RTI is in the business of providing: (1) on-site resin cleaning services for customers primarily in the paper, power, chemical and petroleum refining industries; (2) technical audits for water quality systems; and (3) engineering studies and operator training for water quality systems. Most of its clients are located in the southeastern US. RTI has been in business under various ownership groups since 1989. In 2012 it was acquired by Laurel Capital Partners.

This report (Report) addresses RTI's resin cleaning services, focusing on the technology and performance. It assesses the cleaning agent chemistry, resin evaluation capability, and mobile trailer design. The study is based on documentation provided by RTI and information gathered by Black & Veatch. It includes the evaluation of laboratory reports of resin analyses before and after cleaning, as well as customer evaluations. RTI's cleaning processes are compared to alternative approaches, and RTI's safety procedures and field safety record are discussed.

Important findings of this technology review are summarized as follows:

1. RTI has a portfolio of ion exchange resin cleaning protocols developed over the 23 + years that it has been in business. RTI's cleaning protocols are designed to address site specific fouling of both cation and anion resins of all types. RTI claims to have developed specialized techniques and skills to enhance the effectiveness of resin cleaning and to address unique situations that could interfere with effective cleaning of the resins. Black & Veatch believes that these claims are consistent with the information reviewed.
2. RTI maintains a fleet of three fully equipped cleaning trailers and an auxiliary trailer that are dispatched, along with an experienced crew, to provide on-site cleaning services. Black & Veatch reviewed layout sketches, equipment listings, and cleaning procedures and believes the mobile equipment should be capable of successfully cleaning resins.
3. Chemicals used by RTI for resin cleaning and for waste neutralization are commercially available products and include the commodity chemicals sodium hypochlorite, hydrochloric acid, caustic soda, sodium chloride, sodium bicarbonate, sodium bisulfite, chelants, citric acid and surfactants. RTI also uses specialty biocides and proprietary resin-protective chemical formulations. Black & Veatch did not review the proprietary chemical formulations.
4. RTI claims that its resin cleaning processes will increase demineralizer throughput, reduce the number of regenerations, and lower cost of operation by using less acid and caustic. Black & Veatch reviewed resin cleaning reports and found that measured resin performance parameters are typically restored to some extent. Black & Veatch believes that improved resin performance parameters can generally be translated to improved demineralizer performance. Customer interviews verified that demineralizer performance improved after RTI's resin cleaning and the customers stated their satisfaction with the services provided by RTI.

5. The most frequently used procedures offered by RTI are:
- ReStore CAS, a double acid cleaning of cation resin with hydrochloric acid preceded by surfactant cleaning
 - ReStore CES, chelant cleaning of cation resin with EDTA preceded by surfactant cleaning.
 - ReStore +, RTI's patented process for cleaning Type 1 strong base styrenic anion resin involving proprietary methodology for enhanced reduction of organic fouling.
 - ReStore ATB, a highly developed triple brine/caustic procedure for reduction of organic fouling of weak or strong base anion resin.

6. Black & Veatch reviewed cleaning reports submitted by RTI and found that:
- ReStore CAS removed virtually all particulate fouling (silt) as claimed, removed >50 percent of iron in five of six cases reported, and reduced calcium to <50 g/ft³ in half the cases reviewed.
 - ReStore CES removed virtually all silt as claimed and achieved the hardness reduction claim of <10 g/ft³ in about two thirds of the cases reviewed.
 - ReStore + consistently achieved nonspecific claims for reduction in organic fouling and increase in salt splitting capacity.
 - ReStore ATB consistently achieved nonspecific claims for reduction in organic fouling but to a lesser degree than ReStore +.

Black & Veatch believes that these results indicate that RTI's cleaning procedures are effective, but given the nature and variability of resin fouling, and local conditions, results can vary.

7. RTI states that ReStore + cleaning procedure does not affect the integrity of strong base Type 1 styrenic resin and provides added value to the customer by increasing the useful life of the resin. RTI explained that several customers have used ReStore + since its commercial introduction over six years ago, and report the extension of useful resin life. Black & Veatch acknowledges the capability of ReStore + cleaning to extend the useful life of resin.
8. Methods used by RTI to validate resin cleaning results include resin analysis before and after cleaning; a run extension test developed by RTI to simulate resin performance under actual field operating conditions; and monitoring demineralizer performance after cleaning. Black & Veatch believes that the run extension test appears to be a more accurate method than industry standard test methods to predict resin performance improvement due to cleaning.
9. Black & Veatch reviewed information related to RTI's safety program, including employee safety training requirements, and believes the program is consistent with industry practices. No reportable chemical spills have occurred over the past 11 years according to RTI. No lost work accidents were recorded in the OSHA reports reviewed by Black & Veatch for the time period of 2010 through 2012. Black & Veatch believes that the information reviewed indicates that RTI is capable of performing resin cleaning safely.

10. Black & Veatch believes that RTI's mobile cleaning service has the following competitive advantages over alternative methods of addressing resin fouling:
 - ReStore + is a patented process not available to others for removing organic fouling from strong base Type 1 styrenic resin and appears to have advantages compared to brine-caustic cleaning.
 - RTI has mobile cleaning capability that appears to be unique in the industry.
 - RTI has a comprehensive portfolio of cleaning protocols and procedures and a record of successful cleanings.
 - RTI offers a single source of technical guidance and support services, including laboratory testing of resins, which Black & Veatch believes is not generally available from other sources.

11. Black & Veatch performed four interviews with RTI customers. All of the customers interviewed indicated an improvement in demineralizer operations and a high degree of satisfaction with the services provided by RTI. Customers generally consider resin cleaning to be a maintenance operation that is performed when demineralizer performance begins to deteriorate. RTI is generally relied upon by its customers to determine the condition of the fouled resins and to recommend the appropriate actions.