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Standard Guide for Carbon Reactivation[1]

This standard is issued under the fixed designation D6781; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This set of guidelines is offered to users of activated carbon to provide a better understanding of the reactivation process and some of the problems associated with sending carbon offsite or to a third party for thermal reactivation. It is not intended to serve as an operating procedure for those companies or persons that actually operate reactivation facilities. This is true because each reactivation facility is unique, using different types of furnaces, using various operating and performance requirements, and running spent activated carbons either in aggregate pools (combining different suppliers of carbon) or in custom segregated lots. Additionally, proprietary information for each facility relative to the particular equipment used cannot be addressed in a general set of guidelines.

1.2 *This standard does not purport to address any environmental regulatory concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate practices for reactivation prior to use.*

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2652 Terminology Relating to Activated Carbon

2.2 *Other Standard:*

AWWA B605-99 Standard for Reactivation of Granular Activated Carbon

3. Terminology

3.1 *Definitions:*

3.1.1 *reactivated carbon*—spent activated carbon that has gone through a thermal reactivation process.

3.1.2 *spent activated carbon*—activated carbon that has seen service in some application, and that has some adsorbate on the carbon.

3.1.3 *virgin carbon*—activated carbon produced from a raw material carbon source that has never seen service.

4. Procedure

4.1 *Thermal Reactivation Process:*

4.1.1 In order to appreciate the parameters or properties of the spent activated carbon that influence the success of the reactivation process, one must have a basic understanding of the reactivation process and the equipment used therein. Basically, the equipment and process used for reactivation is similar, if not identical, to those same items used for activation of coal, coconut, wood, or other chars, into activated carbon, post devolatilization and carbon fixation (which are necessary steps in virgin carbon manufacture).

4.1.2 The equipment used for these types of processes usually consists of rotary kilns, vertical tube furnaces, fluidized beds, or a multiple-hearth furnace. All of these can be fired directly or indirectly. Auxiliary equipment to the furnace or kiln consists of feed screws, dewatering screws, direct feed bins, dust control equipment, product coolers, screening equipment, off-gas pollution abatement equipment, and tankage.

4.1.3 The spent carbon can come from either liquid or gas phase service. Thus, the spent carbon will contain more or less water (or other liquids) depending on its service—less for gas phase service compared to liquid phase service. Additionally, the carbon could be fed to the furnace as a water slurry if received in a bulk load, or if the spent carbon was slurried out of adsorbers. Gross dewatering of such a slurry is normally done by gravity separation of the water from the carbon in an inclined dewatering screw.

4.1.4 Once the spent carbon is introduced into the reactivation furnace, the carbon undergoes a three-step process. As the

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

spent carbon progresses through the furnace and is heated up, the carbon first loses moisture and light volatiles; then the carbon loses heavier volatiles by a combination of vaporization, steam stripping, and thermal cracking of heavies into a pseudo-char which deposits in the pores of the carbon; and then, the char is removed from the pores by gasification with steam. This three-step process normally relies on the carbon being heated from ambient temperature to a temperature approaching 1010 °C (1850 °F), with a reactivated carbon discharge temperature of 871 to 954 °C (1600 to 1750 °F) being typical. The steam ratio used is normally 1:1, with the pounds of steam added to the furnace equal to the discharge rate of reactivated carbon leaving the furnace. This ratio can be adjusted up or down depending on the relative quality of the spent activated carbon and the relative reactivated carbon quality being produced, with higher quality (for example, higher iodine numbers, higher carbon tetrachloride numbers, etc.) and harder to reactivate carbons demanding more steam. Spent carbons that have seen light service or are easy to reactivate will demand less steam.

4.2 *Reactivation Guidelines:*

4.2.1 The purpose of the reactivation process is to remove the accumulated contaminants from the activated carbon pores without damaging the carbon backbone. As described above, this is done by a combination of devolatilization, steam stripping, thermal cracking, and gasification. Thus, anything that increases the severity of the operation in terms of spent carbon loading (that is, the amount of contaminants to be removed), the tendency of the contaminants to create char, the presence of higher boiling materials, or refractory material (that is, material inert to devolatilization or gasification) makes the reactivation process less effective, even unattractive, in terms of yield, cost effectiveness, or product quality for reuse. Ideally, reactivation leads to optimally restoring the adsorptive properties of the granular activated carbon while maintaining the carbon's physical properties (especially mechanical strength, density, and particle size). These two requirements do conflict to some extent; for example, reactivation conditions severe enough to optimize adsorption properties may result in unacceptable decreases in mechanical strength and density at the same time. This means that an optimal balance has to be found between restoring adsorption properties and maintaining physical properties. Additionally, any non-carbon material that is introduced with the spent carbon into the furnace, for example, sand, ceramic or metallic bed support material, sludges, oils, etc., reduces the final product quality in terms of adsorptive capacity.

4.2.2 With this in mind, the normal applications for carbon that cover a broad spectrum of applications and industries do not present any restrictions to the use of reactivation services to achieve good yields and good product quality. These applications include potable water dechlorination, taste and odor removal, underground tank remediations, standard wastewater treatment applications, most fugitive emission control applications, most solvent recovery applications, and most chemical purification applications. A good reference for reactivation of granular activated carbon used in the drinking water market is standard AWWA B605-99. However, there are several applications that require special care in the use of reactivation services, or that may not be able to be reactivated economically. The following guidelines apply:

4.2.2.1 Carbon used in sweetener applications must be thoroughly "sweetened off," that is, have as much residual sugar or other large size organic molecules washed off the spent carbon as possible before charging to the reactivation furnace. Otherwise, the sugars will caramelize inside the pores during reactivation and lessen product quality and rate through the furnace.

4.2.2.2 Similarly, carbon used for decaffeination of coffee must also be thoroughly "sweetened off" before charging to the reactivation furnace.

4.2.2.3 Carbons that are contaminated with large amounts of inorganic salts, gangue, fused salts, calcium oxide, or water hardness solids by contact with process waters or solutions also make poor quality reactivated products. There may also be potential leaching problems from the reactivated product (for example, accumulated aluminum from alkaline reactivated carbon). They may also cause problems with furnace slagging, and afterburner slag formation. (Slag is the formation of fused inorganic materials, that may result in large masses that may plug up the furnace or afterburner flow passages.) It is suggested that a test reactivation be done on these carbons to determine if reactivation can be done economically. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.4 Carbons that are contaminated with silanes, siloxanes, or organosilicones may cause problems with furnace slagging, and afterburner slag formation. It is suggested that a test reactivation be done on these carbons to determine if reactivation can be done economically. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.5 Carbons that retain large amounts of sludge or oils from their applications represent handling problems to reactivators that result in higher handling costs and reduced throughputs, and thus, increased overall costs. Additionally, the sludge or oil may polymerize into a refractory coke that would reduce product quality. It is suggested that a test reactivation be done on these carbons to determine if reactivation can be done economically. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.6 The inclusion of foreign material in any spent carbon should be avoided. Care should be taken to minimize the amount of sand, gravel, support material, trash, packaging, etc. contained in any spent carbon that is shipped offsite. This may require close supervision of contract or plant personnel that provide removal services for the carbon, or that haul the carbon to prevent these problems.

4.2.2.7 Carbons that are wood-based, including those used in gasoline vapor recovery units, present some problems to reactivators due to the fact that wood-based carbons are softer than coal-based carbons, and thus suffer higher attrition losses, and because they are lower in density than coal-based carbons and may float in water slurries. Overall yields and handling costs may suffer as a result. It is advisable to get some indication from the reactivator of whether these concerns will have a negative impact before committing to reactivation. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.8 Some solvent recovery unit carbons, particularly those that are used in magnetic tape applications, suffer from poor quality outputs from reactivation. Additionally, carbons used in solvent recovery of ketones can have their pores filled irreversibly with the polymerization product of the ketone (for example cyclohexanone) being used and may be unsuitable for thermal reactivation. Activated carbon used for ketone solvent recovery should be very thoroughly steamed before removal from the adsorber bed and submitted for reactivation. It is suggested that a test reactivation be done on these carbons to determine if reactivation can be done economically. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.9 Carbons that have long service lives, such as gasoline vapor recovery units, and carbons that have been exposed to high abrasive service, usually have a high fines content. These fines may present handling problems whether unloaded by slurry or by vacuum. Overall yields and handling costs may suffer as a result. It is advisable to get some indication from the reactivator of whether these concerns will have a negative impact before committing to reactivation. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.10 Carbons used in liquid phase styrene removal applications present a problem with reactivated carbon "bleed" of residual styrene even after processing. This is not true of carbons used in vapor phase styrene removal applications. It is suggested that the reactivation of the liquid phase carbons be done via custom segregated reactivation, rather than pool reactivation, so as to prevent passing styrene into streams where it would not normally be present.

4.2.2.11 Some carbons have been used as inoculation sites for bacteria to perform specialized chemical recoveries. Other carbons have been exposed to services wherein bacterial or organic plant growth has been rampant. It is suggested that these carbons not be reactivated, but rather disposed of.

4.2.2.12 Carbons that have been used for organic removal from hydrochloric acid can be exposed to iron pickup during reactivation. Users of reactivation services should be aware of this possibility.

4.2.2.13 There are some environmental treatment aspects associated with reactivation that may add significant costs; highly loaded carbons with significant amounts of halides or sulfur compounds engender additional treatment and disposal costs when these compounds are removed from the spent carbon. Carbons loaded with high amounts of fluorides, such as refrigerants, hydrogen fluoride, etc., may engender additional costs for processing by attacking furnace refractories, which will require replacement, as well as increasing treatment costs. Carbons loaded with high amounts of metals engender lower throughputs and additional treatment and disposal costs as well. It is advisable to get some indication from the reactivator of whether these concerns will have a negative impact before committing to reactivation. Additionally, the economics can be influenced by whether these carbons are run in a segregated, or pool, manner.

4.2.2.14 If any reactivation of carbon used in nuclear applications is undertaken, special precautions are necessary to control any radiological offgassing. Therefore, reactivation of carbon from nuclear applications may require special considerations. It is advisable to get some indication from the reactivator of whether these concerns will have a negative impact before committing to reactivation.

5. Keywords

5.1 activated carbon; guidelines; reactivation