Public Comments on Proposed Revisions to the Control Cost Manual
Section 3.1
Chapter 1: Carbon Adsorbers

Contents

List of Commenters

Document Control Number	Commenter Name	Commenter Affiliation
EPA-HQ-OAR-2015-0341-0049	Anonymous	
EPA-HQ-OAR-2015-0341-0050	Theodore Steichen, Senior Policy Advisor	American Petroleum Institute (API)
EPA-HQ-OAR-2015-0341-0051	Ryan Streams, Manager	Western Energy Alliance
EPA-HQ-OAR-2015-0341-0052	David Friedman, Vice President, Regulatory Affairs	American Fuel and Petrochemical Manufacturers (AFPM)

1.1 Introduction

Commenter: Anonymous
DCN: EPA-HQ-OAR-2015-0341-00

Comment: The commenter recommended the following text be added to section 1.1 of the draft chapter (Introduction) after "volatile organic compounds (VOCs)": **"and other compounds such as hydrogen sulfide.**" The commenter noted that adsorption is a non-destructive control technology employed to remove volatile organic compounds (VOCs) and other compounds such as hydrogen sulfide.

Response: The EPA agrees with the commenter's recommendation and has added the following sentence to the end of Section 1.1 of the final chapter to clarify that adsorbers can be used to control other pollutants:

> "While this chapter focuses primarily on VOC control, carbon adsorption is also used to control hazardous air pollutants (HAP), including inorganic HAPs such as hydrogen sulfide."

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052

Comment: Comments on the Accuracy of the VOC Removal Efficiency Estimates

In response to EPA's question on the VOC removal or control efficiency for carbon adsorbers, the commenter agreed with EPA's approach of including only general information rather than definitive VOC removal efficiencies for carbon adsorbers. The commenter agreed with the information presented in Section 1.6.3 (page 1-25) of the draft chapter (renumbered as Section 1.8.3 in the final chapter). Specifically, the commenter agreed that VOC removal efficiency for carbon adsorption systems is a function of time and depends on several factors, including the specific VOC constituents to be adsorbed, the type of carbon used and the physical characteristics (temperature, humidity, etc.) of the adsorber feed stream.

Response: The EPA agrees with the commenter that several factors impact the removal efficiencies for carbon adsorbers. We have added the following text to Section 1.1 of the final chapter to clarify that carbon adsorbers can achieve high VOC removal efficiencies when properly designed and operated:

> "When properly designed, operated and maintained, carbon adsorbers can achieve high VOC removal efficiencies of 95 to 99 percent at input VOC concentrations of between 500 and 2,000 ppm in air. Removal efficiencies greater than 98 percent can be achieved for dilute waste streams. [20, 21]"[1,2]

---

[1] U.S. EPA, *Carbon Adsorption for Control of VOC Emissions: Theory and Full Scale System Performance",* Office of Air Quality Planning and Standards, EPA-450/3-88-012, June 1988.

[2] Lawrence K. Wang, Yung-Tse Hung, and Naxih K. Shammas, *Handbook of Environmental Engineering: Physicochemical Treatment Processes,* Humana Press, volume 3, 2004, page 570-571.

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052

Comment: Other Types of Adsorbent Media

The commenter said that the revised chapter fails to address other types of adsorbent media that are in widespread use in the air pollution control industry. The commenter recommended the EPA discuss synthetic and naturally-occurring zeolites, silica gel, activated alumina, and fuller's earth. The commenter said that the EPA justifies not including further description of these alternative media options by stating that activated carbon is the most commonly used adsorbent for volatile organic compounds (VOC). The commenter argued that technical advances in the use of other adsorbent materials have been made over the years and encouraged the EPA to include more up-to-date information about other media and the emission control situations in which other media would be superior to carbon. As an example, the commenter said that multiple manufacturers offer rotary adsorbers (often referred to as concentrators) that utilize zeolite, for use either alone (for solvent recovery) or in front of an oxidizer (to concentrate the air stream that goes to the oxidizer upon regeneration of the adsorbent in the wheel). The commenter said that these units are commonly included in certain VOC BACT analyses.

Response: The EPA agrees with the commenter's recommendation and has added a new section that provides detailed descriptions of currently available alternative adsorbent materials (see Section 1.3 in the final chapter).

1.2 Types of Adsorbers

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052

Comment: General Descriptions of Carbon Adsorbers

In response to EPA's question regarding whether the description of carbon adsorbers is complete, up-to-date, and accurate, the commenter said the process descriptions for carbon-based fixed-bed and canister adsorber systems presented in Section 1.2 of the draft chapter appear to be reasonably complete and accurate.

Response: The EPA thanks the commenter for their input.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: On page 1-2 and 1-3 (Section 1.2 of the draft chapter), the commenter disagreed with the discussion of intermittent operations and with the statement that steam is usually used to desorb the carbon beds. The commenter said that vacuum desorption and pressure swing adsorption are also commonly used and may be more common than steam desorption today. The commenter said that several major manufacturers provide package systems. The commenter suggested these systems be described and the cost sections be more clearly identified as being limited to fixed bed, steam regenerated adsorption systems.

Response: The EPA agrees with the commenter's recommendations. We have added a new section that provides detailed descriptions of the alternative methods for regenerating the adsorbent (see Section 1.4 in the final chapter).

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052

Comment: Traveling bed adsorbers, fluid bed adsorbers, and chromatographic baghouses.

In response to EPA's question regarding whether the description of carbon adsorbers is complete, up-to-date, and accurate, the commenter said that the chapter lists other types of carbon adsorption systems (i.e., traveling bed adsorbers, fluid bed adsorbers, and chromatographic baghouses) but provides little technical information about these other types of systems. The commenter said that revised chapter does not provide any information on the current state of their commercial applicability or the reasons for their potential suitability.

Response: The EPA agrees with the commenter's recommendation and has added new subsections that provide detailed descriptions of the moving-bed and fluid-bed adsorber designs (see Sections 1.2.3 (Moving-Bed Adsorbers) and 1.2.4 (Fluid-Bed Adsorbers) in the final chapter). We have removed the reference to "chromatographic baghouses" in Section 1.2 (Types of Adsorbers) as we were unable to identify sources currently using this technology.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: If steam is used in regeneration of the adsorbent, the commenter said that the desorbed hydrocarbon and associated water must be either discarded as waste or separated. The commenter contended that costs for wastewater handling facilities may be significant even if the hydrocarbon and water is just being sent to wastewater treatment or to a tank for eventual loading into a truck for shipment offsite. The commenter recommended alternative approaches to handling the desorbed materials be described and that the chapter clarify that the capital and operating costs for waste handling must be estimated separately and added to the carbon adsorption system costs.

Response: The EPA agrees with the commenter that adsorbers using steam-based regeneration processes must include capital and operating costs for disposing of the wastewater at a treatment plant and/or recovery of VOCs. Typically, the VOCs are separated using a decanter or condenser. The recovered VOC can either be sent for disposal or reused onsite. We have added a new section that provides a detailed description of the Temperature Swing Regeneration method that includes a discussion of the recovery of VOCs and the need to include capital and operating costs for VOC recovery and/or waste handling and disposal (see Section 1.4 (Adsorbent Regeneration) in the final chapter).

1.2.1 Fixed-Bed Units

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter disagreed with the sentences: "The desorption cycle usually lasts 1 to 1½ hours. The unit sits idle until the emission source starts operating again." The commenter said that regeneration time is a function of several factors including unit size and hydrocarbon loading. Based on their experience, the commenter said that 1 to 1 1/2 hours was an unusually short time. The commenter recommended that no time be specified.

Response: The EPA agrees with the commenter that desorption times are variable and depend on several factors, including the size of the carbon bed, types of VOC adsorbed, the type of adsorbent, and the regeneration method. We replaced the existing sentences in Section 1.2.1 of the final chapter with the following:

> "The length of the desorption cycle depends on several factors, including the characteristics of the contaminants in the waste stream, the type of adsorbent, and the regeneration method. The unit sits idle until the emission source starts operating again (for systems controlled by a single adsorber) or another adsorber is taken off-line for regeneration (for systems equipped with two or more adsorbers)."

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: In Section 1.2.1 (page 1-2 of the draft chapter), the commenter disagreed with the statement that fixed-bed units can handle streams up to 25% of the VOC's lower explosive limit (LEL). The commenter said that the feed to commercial fixed-bed carbon adsorbers (such as those used in terminals) far exceed the VOC's LEL during part of the adsorption cycle. In those cases, the commenter said that inerting is typically used to reduce the risk of ignition. The commenter recommended the EPA clarify that the 25% LEL (the typical maximum level) may be maintained by diluting the gas stream with inert gas.

Response: The EPA agrees with the commenter's statement and has made the following revisions to Section 1.2.1 of the final chapter:

> **"**The VOC concentration of streams that can be treated by fixed-bed adsorbers can be as low as several parts per billion by volume (ppbv) in the case of some toxic chemicals or as high as 25% of the VOCs' lower explosive limit (LEL). **In some applications, the concentration of VOC in the waste gas stream may exceed the LEL. To reduce the risk of ignition, the waste gas stream is diluted to maintain the waste gas VOC concentration below 25% of LEL.** (For most VOCs, the LEL ranges from 2,500 to 10,000 ppmv. [3])"

1.2.2 Canister Units

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter disagreed with the sentence: "Adequate recordkeeping, periodic monitoring for VOC breakthrough, and bed life modeling provided by vendors should be required by regulating agencies to ensure canister replacement occurs with sufficient frequency that VOC breakthrough does not occur" in Section 1.2.2 of the draft chapter. The commenter felt that this sentence suggests canisters are generally not monitored. While the commenter agreed that monitoring is not typically continuous, they said that periodic monitoring or scheduled carbon replacement is required for virtually all regulated vent streams controlled by carbon canisters. The commenter thought that it was outside the purview of the Control Cost Manual to direct regulating entities on what to require in permits. The commenter believed the sentence should be removed as it was inaccurate and inappropriate.

Response: The EPA agrees with the commenter that periodic monitoring for carbon canister systems is typically required by state and local agencies. However, we disagree with the commenter that recommendations regarding appropriate monitoring for control systems is beyond the scope or outside the purview of the Control Cost Manual. Nor do we agree with the commenter that the sentence implies current monitoring and recordkeeping of carbon canisters is insufficient. The sentence referenced by the commenter is primarily to alert regulators and industry of the need for careful monitoring due to the potential for breakthroughs to occur. Careful monitoring and recordkeeping are necessary to ensure canisters function correctly and are replaced in a timely manner, whether any regulation to require this is in place or not. In addition to providing information on costs, the Control Cost Manual provides information on the types of controls available for a particular pollutant, how the control is operated, the types of applications for which they are best suited and the level of control they can achieve. The Control Cost Manual is intended to be a tool to help regulators and industry select control technologies that are appropriate, effective and economical. We believe that including recommendations for monitoring is consistent with this goal and appropriate to include in the manual. However, to address the concerns raised by the commenter and to improve the general discussion of recommended monitoring, we have made the following revisions to the final chapter:

> "Adequate recordkeeping, periodic monitoring for VOC breakthrough, and bed life modeling provided by vendors are **all worthwhile** ~~should be required by regulating agencies~~ to ensure canister replacement occurs with sufficient frequency that VOC breakthrough does not occur. **The primary indicator of the performance is the adsorber outlet VOC concentration. Other indicators of adsorber performance include inlet gas temperature, gas flow rate, inlet VOC concentration, pressure differential, inlet gas moisture content, and leak check monitoring.**"

1.3 Adsorption Theory

No comments received.

1.4 Design Procedure

1.4.1 Sizing Parameters

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter said that Section 1.4.1 (page 1-10) of the draft chapter (renumbered as Section 1.6.1 (Sizing Parameters) in the final chapter) fails to discuss the impacts of water and how it affects the design and cost. The commenter recommended the EPA add a discussion of how moisture impacts the sizing of the equipment. Additionally, the commenter suggested the word "humidity" be changed to "moisture" for consistency with later discussions on the impacts of water.

The commenter recommended the sentence be revised as follows: "The ~~humidity~~**moisture** content of the gas stream, especially in **regard to** the effect of humidity on capacity**, particularly** in relation to **the amount of carbon needed to remove** halogens."

Response: The EPA agrees with the commenter that the amount of moisture in the waste gas stream must be considered when designing an adsorber. We have included the following additional text to clarify the effective approaches for the use of a carbon adsorber for waste streams with high moisture content:

> "(5) The ~~humidity~~ **moisture content** of the gas stream~~, especially in the effect of humidity on capacity in relation to halogens~~.

In addition, the cost could also be affected by other stream conditions, such as the presence/absence of excessive amounts of particulate, moisture, or other substances **that** ~~which would~~ require the use of extensive pretreatment and/or corrosive-resistant construction materials. **If the inlet concentrations are above 1,000 ppm, the moisture content does not significantly affect the working capacity of activated carbon. However, if the VOC inlet concentration is below 1,000 ppm or the relative humidity is above 50%, then the moisture begins to compete with the adsorbate for the available adsorption sites. If the VOC concentration is below 1,000 ppm or the waste gas has a relative humidity above 50%, then dehumidification equipment can be used to reduce the moisture content of the waste stream before it enters the adsorber vessel. Alternatively, a zeolite or synthetic polymer adsorbent may be used that has lower affinity for water molecules than activated carbon. Zeolite and synthetic polymer adsorbents are effective for waste streams with high moisture contents. Many zeolites and polymers are effective up to a relative humidity of 90%. [18, 21, 22, 23]"**

1.4.2 Determining Adsorption and Desorption Times

No comments received.

1.4.3 Estimating Carbon Requirement

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: In Section 1.4.3.2 (pages 1-12 and 1-13) in the draft chapter (renumbered as Section 1.6.3.2 (Carbon Estimation Procedure), the commenter disagreed with the procedure for estimating the amount of carbon required because it can cause the amount of carbon to be underestimated, resulting in a low-cost estimate. The commenter raised the following two issues:

1. The carbon estimate is based on the VOC inlet loading, m_{voc} and the adsorption time, Θ_A. The VOC loading is usually quite variable, but the system must always assure compliance. Thus, the loading that is the basis for the design must be the maximum loading. The commenter said that it was not clear in the procedure that the maximum loading should be used. They believed users may mistakenly assume that an average loading should be used to calculate the carbon charge. The commenter recommended the term m_{voc} be redefined as the “maximum VOC inlet loading”

2. When a carbon adsorption system is used as a control device, it must always meet the control requirement. Since, frequent shutdowns of a control device (e.g., for carbon replacement) is not acceptable, it is typical to design the system with a safety margin. That is, extra carbon is included to assure compliance, even if the carbon is degraded (e.g., at the end of its usable life or degraded due to impurities in the inlet stream). The commenter recommended the calculated carbon quantity be increased to provide this margin of safety. The commenter said that carbon in a single bed or set of beds that operate simultaneously must be adequate to assure compliance for the entire time required for a full regeneration of the equivalent bed or set of beds that alternate with the primary bed or set of beds.

Response: The EPA agrees with the commenter that the VOC inlet loading should be the maximum loading and not the average loading for systems where the VOC content of the waste stream is variable. We have revised the definition of the term m_{voc} in Section 1.6.3.2 (Carbon Estimation Procedure) of the final chapter and added text to clarify that the maximum loading should be used to determine the amount of adsorbent required.

We disagree with the commenter that an additional factor is needed to allow for a margin of safety. The amount of adsorbent is estimated based on the working capacity of the adsorbent, which is calculated by multiplying the equilibrium capacity by a factor of 0.5 (see Equation 1.15 in the final chapter). Additionally, the note included below Equation 1.15 states that the 0.5 factor should be lowered to account for situations where more conservative (that is, higher) carbon estimates are appropriate and provides several examples of situations where a factor lower than 0.5 should be used. Thus, a safety margin is essentially incorporated in the adsorbent estimation approach.

1.5 Estimating Total Capital Investment

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Cost Estimating Discussion for Fixed-Bed, Steam Regenerated Adsorbers (Section 1.7.1 in the final chapter).

The commenter said that the approach presented applies only to fixed-bed systems using steam regeneration. The commenter recommended the EPA clarify in the introduction and section headings that the method described in this section does not apply to systems using vacuum desorption and pressure swing systems. The commenter noted that vacuum desorption and pressure swing desorption systems are commonly used today.

Response: The EPA agrees with the commenter that the methods outlined in Section 1.5 of the draft chapter (Section 1.7.1 in the final chapter) apply only to fixed-bed carbon adsorbers. For the purposes of clarification, the following changes were made to Sections 1.5 and 1.5.1 of the draft chapter (renumbered as Sections 1.7 and 1.7.1 in the final chapter):

> "**This section describes the procedures that can be used to estimate the purchased costs for fixed-bed and canister-type carbon adsorbers. Since** ~~E~~**entirely** different procedures ~~should be~~ **are** used to estimate the purchased costs of fixed-bed and canister-type adsorbers, **the two systems are** ~~Therefore, they will be~~ discussed separately."

Section 1.7.1 in the final chapter was revised as follows:

> "As indicated in the previous section, the purchased cost **for fixed-bed carbon adsorbers using steam regeneration** is a function of the volumetric flow rate, VOC inlet and outlet loadings, the adsorption time, and the working capacity of the activated carbon. As Figure 1.1 shows, the adsorber system is made up of several different items. Of these, the adsorber vessels and the carbon comprise from one-half to nearly 90% of the total equipment cost. (See Section 1.~~5~~**7**.1.3.) There is also auxiliary equipment, such as fans, pumps, condensers, decanters, and internal piping, but because these usually comprise a small part of the total purchased cost, they may be "factored" from the costs of the carbon and vessels without introducing significant error **into a cost estimate at a study-level of accuracy, as this one is**. The costs of these major items are considered separately."

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050
Comment: Purchase Equipment Costs

The commenter expressed concern that the cost estimates developed following the suggested procedures reflect only a fraction of actual costs and consequently could bias regulatory decision making. The commenter said that the chapter is based on 1980's technology and cost data and does not account for changes in design practices and regulations. For instance, the cost estimates should reflect the design practice of providing 100% capacity carbon beds in series, to assure compliance while the primary bed is being replaced or desorbed.

Response: The EPA thanks the commenter for their input and notes that the Agency attempted to collect more current data on both costs and technology advances through extensive searches of various information sources, including databases (e.g., the EPA's RACT/BACT/LAER Clearinghouse), construction permits, journal articles, vendor information, EPA documents, and conference presentations. However, the cost data we collected was not sufficient to allow us to develop new cost correlations. For this reason, we specifically solicited comment on cost correlations, factors, and equations and asked for input on how the capital and operating costs should be updated (see 81 FR 65353, July 21, 2017). We have received updated information on activated carbon and canister costs from vendors since the NODA was issued, and that data has been included in the chapter. Although we agree with the commenter's remarks regarding the age of the data and the problems associated with scaling the data to current costs, the cost correlations for fixed-bed adsorbers with steam regeneration included in the Manual nevertheless represent the best data currently available to us.

Although the data used to develop the cost correlations for the fixed-bed adsorber is dated, we concluded that this data was still useful for developing the study-level capital and operating cost estimates for which the Cost Manual is designed. Consequently, we have retained this data in the final chapter. However, we also agree with the commenter that these study-level estimates should not be the only information used to select a control device. Selection of a control device should always be based on a detailed engineering study and cost quotations from system suppliers, rather than solely on the study-level estimates provided by the Cost Manual. For cost analyses conducted under the authority of the Regional Haze program, such as for Best Available Retrofit Technology (BART) and reasonable progress determinations, the NAAQS implementation program, such as for Reasonably Available Control Technology (RACT) determinations and Best Available Control Technology (BACT) determinations, detailed itemized costs with appropriate documentation must be prepared for each control technology and reviewed by agency staff to ensure the costs provided are complete, correctly calculated, and supported by the documentation.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050
Comment: Purchase Equipment Costs

The commenter recommended the EPA obtain current vendor estimates for packaged carbon adsorption units and canister systems of various capacities, reflecting current design practices, and to use those as the basis for the associated equipment ratio and the total equipment cost. The commenter said that Purchased Equipment Costs for field erected units should be based on actual major equipment lists, rather than on the ratio method described in the chapter.

The commenter said that apart from the fabricated material factor (F_m), the cost equation is exactly the same as Equation 4.20 presented in the Fourth Edition of this Chapter and Equation 1.25 presents vessel cost information on the basis of 1989 dollars, noting that these data are nearly 30 years old. The commenter similarly noted that the unit cost information for replacement carbon presented in Section 1.5.1.1 of the draft chapter (renumbered as Section

1.7.1.1 in the final chapter) is the same unit cost presented in Section 1.3.1.1 of the Sixth Edition of this Chapter, which is 18 years old.

The commenter noted that the EPA has previously stated that the Chemical Engineering Plant Cost Index (CEPCI) can be used to adjust nominal equipment costs from a base year to real equipment costs for the current year. However, the commenter noted that in the draft Seventh Edition of Section 1, Chapter 2 of this Manual ("Cost Estimation: Concepts and Methodology"), the EPA states that the accuracy associated with escalation of equipment costs in this fashion declines the longer the time period over which escalation is done and that escalation of equipment costs that are more than five years old is not considered to be appropriate because it "…does not yield a reasonable accurate estimate." The commenter argues that the cost information presented in this chapter is too old to be used in conjunction with the CEPCI escalation procedure advocated by the EPA.

The commenter further stated that the EPA has not considered the impact of other influences on equipment and operating costs, such as energy efficiency, changes in the carbon regeneration and disposal industry, and regulatory changes (*e.g.*, the Resources Conservation and Recovery Act, Benzene Waste Operations NESHAP), that have had a direct impact on the capital and operating costs associated with carbon adsorption systems.

The commenter recognized that gathering, compiling, and maintaining current and accurate cost information on air pollution control systems is a time-consuming and resource-intensive endeavor. The commenter further recognized that current Agency budget and resource constraints may make it difficult. The commenter suggested the EPA hire an engineering firm to assemble cost information, as an actual equipment buyer would do. This alternative is practiced by other branches of the Federal government that have similar needs for accurate and current cost information. For example, the commenter noted that the National Energy Technology Laboratory (NETL) of the Department of Energy recently published a series of studies on the costs and performance of fossil fuel-fired electric generating plants. NETL hired the engineering firm Worley Parsons to gather equipment quotes from vendors for major equipment items and to use Worley Parsons' equipment cost database to calculate current costs of new power plants of several alternative configurations. The commenter said that hiring an engineering firm to generate current cost data for air pollution control systems would be a faster and more accurate way to update the Manual equipment cost data.

The commenter said that the cost estimates for the various elements of carbon adsorption systems should be presented on the basis of the year in which the chapter revision will be finalized (*e.g.*, 2017 or 2018).

Response: The EPA thanks the commenter for their input and note that the EPA attempted to collect more current data on both costs and technology advances through extensive searches of various information sources, including databases (e.g., the EPA's RACT/BACT/LAER Clearinghouse), construction permits, journal articles, vendor information, EPA documents, and conference presentations. However, the cost data we collected was not sufficient to allow us to develop new cost correlations. For this reason, we specifically solicited comment on cost correlations, factors, and equations and asked for input on how the capital and operating costs should be updated (see 81 FR 65353, July 21, 2017). We have received updated information on activated carbon and canister costs from vendors since the NODA was issued, and that data has been included in the chapter. Although we agree with the commenter's remarks regarding the age of the data and the problems associated with scaling the data to current costs, including concerns with the timeframe over which escalation takes place, the cost correlations included in the Manual nevertheless represent the best data currently available to us for fixed-bed adsorbers with steam regeneration.

Although much of the data used to develop the cost correlations is dated, we concluded that this data was still useful for developing the study-level capital and operating cost estimates for which the Cost Manual is designed. Consequently, we have retained this data in the final chapter. However, we also agree with the commenter that these study-level estimates by themselves should not be used to select the most cost-effective control device. Selection of the most cost-effective option for a control device should always be based on a detailed engineering study and cost quotations from system suppliers, rather than on the study-level estimates provided by the Cost Manual. For cost analyses conducted under the authority of the Regional Haze program, such as for Best Available Retrofit Technology (BART) and reasonable progress determinations, Reasonably Available Control Technology (RACT) determinations, and Best Available Control Technology (BACT) determinations, detailed itemized costs with appropriate documentation must be prepared for each control technology and reviewed by agency staff to ensure the costs provided are complete, correctly calculated, and supported by the documentation.

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052
Comment: Accuracy of Cost Information Presented – Impact of Facility Elevation

The commenter said that the cost estimating methodology presented does not account for the impact a facility's elevation with respect to sea level has on the design and equipment cost for fixed-bed adsorption systems. The commenter noted that the methodology presented in Section 2.4.1 of the Manual chapter on selective catalytic reduction for nitrogen oxide (NOx) control, in which base equipment and balance of plant costs are proportional to the ratio of the atmospheric pressure between sea level and the location of the system, is an appropriate way to account for the cost increase associated with systems at higher elevations.

Response: The carbon adsorber sizing procedures and capital costs are based on actual gas flow rates. Thus, adjustments to account for the effect of elevation are not needed.

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052
Comment: New Systems versus Retrofits

The commenter notes that the cost information applies only for new installations and that no cost data for retrofit carbon adsorption systems is included. The commenter said that retrofit costs are a very important topic for the regulated community because there are many instances where the possible cost impact of the addition of emission control systems on existing sources must be considered (*e.g.*, prospective MACT standards for existing sources or other BACT or RACT control cost analyses for modifications to existing sources). The commenter said that the EPA has previously stated that no definitive retrofit factors or rules can be developed because each existing source is unique. Nonetheless, the commenter said that retrofits are significantly more expensive than new installations and having more definitive guidance or a range of expected retrofit ratios for the various elements of a carbon adsorption system would be a helpful addition to this Chapter.

Response: The EPA agrees that the effect of a retrofit factor in cost estimation is important. The importance of retrofit factors in cost estimation is discussed in the cost methodology chapter of the Control Cost Manual. The EPA has not found any information on the degree of difficulty for retrofits that is applicable or typical for capital cost estimation for carbon adsorbers. However, EPA will include a capability for a user to estimate the costs of retrofits for a carbon adsorber in the cost spreadsheet that will be provided to the public along with the final Carbon Adsorbers chapter.

Commenter: Anonymous
DCN: EPA-HQ-OAR-2015-0341-0049

Comment: The commenter recommended the costs for carbon adsorption controls be escalated to reflect 2014 dollars.

Response: It is the EPA's preference to provide the costs for carbon adsorber controls for the year for which they were available. Therefore, the EPA has chosen not to escalate the capital costs in this chapter for the fixed-bed adsorber. Operating and maintenance costs should not be escalated as stated in the Control Cost Manual's cost methodology chapter (Section 1, Chapter 2). Users are welcome, however, to escalate or deescalate capital costs for carbon adsorbers using cost and other indexes mentioned in the aforementioned cost methodology chapter of the Control Cost Manual.

Commenter: Western Energy Alliance
DCN: EPA-HQ-OAR-2015-0341-0051

Comment: The commenter said that the Control Cost Manual does not address the control devices of the size and design used in the upstream segment of the oil and natural gas industry. The commenter encouraged the EPA to clarify which industries and industry segments should use the manual for guidance and cost analysis. The commenter noted that smaller, more dispersed facilities common to oil and natural gas production use different control device designs and have different economic considerations from large gas plants, chemical plants, and refineries. The commenter recommended the EPA clarify that the Control Cost Manual is not suited to analyzing control device costs for small upstream facilities. The commenter said that adding a clarification statement would avoid situations where the Control Cost Manual is used for small sites. The commenter was concerned the Control Cost Manual would be applied incorrectly to small facilities and lead to flawed cost-benefit analysis in future regulations or project-specific requirements. The commenter recommended the EPA should prepare a separate analysis for small facilities.

Response: The EPA disagrees with the commenter that the Cost Manual is not applicable to smaller industries or emission sources. Although some of carbon adsorbers discussed in the chapter are typically applied to larger emission sources, the carbon adsorber canisters discussed in Sections 1.2.2 and 1.7.2 in the final chapter are applicable to smaller installations. The information provided is not specific to the oil and gas sector. Unfortunately, the commenter did not provide any information on use of carbon adsorption in the upstream oil and gas industry or any cost data specifically related to the oil and gas industry.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050
Comment: Comments on indirect costs

The commenter said that the construction and field expenses factors of 10% and 5% are intended to cover project management, both contractor-provided and owner-provided costs. However, the commenter said 20-40% is typical for project management and oversight based on total project cost, rather than the PEC. The commenter said that the project management costs should be estimated at 20% for a carbon adsorber cost, rather than the 5% included in the chapter, and that these factors should be applied to the total installed cost estimate, not the PEC, since much of the project management involves supervision of the installation. The commenter said that the project costs are typically included in estimates and include the costs for the owner's project personnel. In addition to project management, technical specialist, permitting and general oversight, there are significant owner's field costs including field permits, gas testing, equipment preparation, inspection, operator training and startup.

Response: The EPA disagrees with the commenter's suggestions. The percentages used to estimate carbon adsorber construction and field expenses are reasonable and consistent with other similar control devices. The other percentages included in the Manual also are reasonable, and the commenter provides no data to substantiate their suggestions.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050
Comment: Indirect Costs

The commenter said that the 10% allowed for contractor profit was reasonable, but should be based on total installed cost, rather than just PEC, since installation costs are a significant contract item.

Response: We have revised the contractor profit cost item as recommended by the commenter.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050
Comment: Indirect Costs

The commenter said that the costs of performance tests are not significantly different as a function of throughput, and the indicated cost of 1% of Purchased Equipment Cost (PEC or "B" in Table 1-4 in the final chapter) is meaningless, particularly for smaller units. A more realistic estimate, the commenter asserted, would be $20,000 to $30,000 for a carbon adsorption system, regardless of PEC. In addition, the commenter argued that electronic reporting of performance test results is now required by EPA, which they said adds to the cost of every performance test.

Response: The costs for performance tests are difficult to estimate as many factors affect the number and types of performance tests required. However, we believe the method provided in the Cost Manual is a reasonable approach for study-level cost estimates when these costs are not known. When actual costs for performance tests are available, they should be used to calculate the indirect costs.

We disagree with the commenter that electronic reporting increases the costs of performance tests. Entering data into the electronic reporting system should be no more burdensome than preparing and mailing hardcopy reports required prior to EPA's adoption of the new electronic filing system.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter said that costs for required safety systems should be addressed in the installation factors. While the safety valves themselves may be included in the purchased equipment cost for some of the equipment (e.g., equipment on the carbon adsorber skid), the commenter said they are not normally included in the purchased cost of equipment used for the carbon adsorber system that is not located on the package skid. The associated piping and other facilities are not typically included in the purchased equipment costs and an allowance should be provided if these are not separately estimated. The commenter said connecting safety valves in hydrocarbon service is standard practice and is now EPA policy. The commenter said that these costs must be included in project cost estimates.

The commenter said that an allowance for sewers, firewater systems, safety showers and bringing utilities to the location should also be added. The commenter said that if the safety equipment is considered "site preparation," then the chapter should clarify in the discussion that the safety equipment is included in the "site preparation" estimate.

Response: The EPA disagrees with the commenter that costs for safety systems, such as firewater and safety showers, should be added to the cost methodology. These systems are essential for the safe operation of the production equipment and would be installed even where air pollution control systems are not installed.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The installation cost and indirect expense factors suggested are clearly unrealistic.

The commenter disagreed with the use of generic estimating factors and said that they were not applicable to the petroleum, chemical and other fluid handling industries where there is inadequate data. The commenter said that the installation and indirect costs estimated using the Cost Manual methodologies are very low. The commenter said that the Lang factor is a ratio of the total cost of installing a process in a plant to the cost of its major technical components (See, for instance, Wolf, T. E., *Lang Factor Cost Estimates*, at http://www.prjmgrcap.com/estimateslangfactors.html, 2013). The commenter said that the Lang factors are used to estimate the total equipment cost for a project where detailed information on piping and other auxiliaries are not available. For fluid processing industries, the commenter said that the Lang factor is 4.74 (See Hans Lang, *Cost Relationships in Preliminary Cost Estimation*, Chem. Eng., Oct 1947 and Hans Lang, *Simplified Approach to Preliminary Cost Estimates*, Chem. Eng., June 1948), which implies that the total erected cost for a project at the study level of estimate is typically 4.74 times the purchase cost of the major equipment. The commenter said that the method included in the Cost Manual result in ratios of 1.61, which is significantly below the 4.74 Lang Factor.

Response: The EPA thanks the commenter for their input. We disagree with the commenter that the 4.74 Lang Factor should be used. We have revised the Total Capital Investment (TCI) so that the TCI is:

$$TCI = 1.48B + SP + Bldg + C + \text{Contractor Fees}$$

where

B	=	Purchased Equipment Cost,
SP	=	Site Preparation Cost,
Bldg	=	Costs for Buildings, and
C	=	Contingency (calculated as 5 to 15 percent of the sum of direct and indirect costs).

As shown in the equation, 1.48 times the purchased equipment cost (B) provides a base cost for purchasing and installing control equipment. Users can include additional costs for site preparation, buildings and contingencies, which are costs that were included in the data used to develop the Lang factor. Hence, the 1.48 factor should not be compared with the 4.74 Lang factor as the two values are not comparable. Also, Lang developed factors for different types of facilities (i.e., solid processing plants, solid-fluid process plants and fluid process plants) using data from a limited number of facilities for construction and installation of process equipment, rather than emission control devices. We consider the method included in the Cost Manual to be preferable to the Lang Factor approach for purposes of pollution control equipment cost estimation as it allows users greater flexibility to adjust estimated costs where appropriate to address site preparation, building and other costs that affect a particular project.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on Installation Cost Factors

The commenter said that the allowance of 1% of the major equipment cost included for installing electrical supply to carbon adsorber systems is inadequate. The commenter said that the costs may be adequate for lighting and instrumentation power for a fixed-bed carbon adsorption system but would not cover the electrical supply costs for the required motors. The commenter also said that it was not clear whether the motors are included, except if they are part of the purchased carbon adsorber package. As stated in the draft chapter, a fixed-bed carbon adsorption system has a vent system fan, bed drying/cooling fan, cooling water pump, and solvent pump(s). The commenter said that motor control centers, substation additions and even wiring runs are very costly in refinery and petrochemical locations since they must meet National Fire Prevention Association, National Electrical Code Class I, Division 2 classification and be installed without impacting existing operations. The commenter said every installation is different and electrical costs vary widely depending on the availability of spare substation capacity. The commenter recommended the Cost Manual develop a cost estimate methodology based on the number and size of required motors.

Response: The EPA thanks the commenter for their input. Although we attempted to collect additional information through extensive searches of various information sources, we were not able to collect sufficient data to allow us to develop a new methodology for estimating electrical supply costs. However, the Agency recognizes the need to meet NFPA and other requirements. We specifically solicited cost data in our Notice of Data Availability (see 81 FR 65353, July 21, 2017). The method included in the Cost Manual represents the best approach currently available to us. We consider this method to be reasonable for the study-level estimates for which they were developed.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: A contingency factor of 30% should be used, rather than the 3% suggested.

The commenter said that contingency factors are required for all project cost estimates, since direct estimates, particularly those based on only rough screening quality information, cannot anticipate every project need or impact. For instance, every potential siting and installation issue; every required upgrade to electrical, instrument or other utility services; every labor cost variation; every weather effect; etc. cannot be predicted in a screening quality estimate. The commenter said that project contingency factors used by the petroleum industry typically start quite high (e.g., 30-50%) and are reduced as project detail improves. The commenter noted that even for projects with detailed process designs, project contingencies of at least 10-20% are still required (depending on company practice and experience). The commenter said that 30 – 50% is the amount of contingency typically required for screening estimates, such as those developed through the Control Cost Manual. The commenter recommends a project contingency of at least 30% to improve the probability that the cost estimate reflects the cost (±30%) of the control. Without inclusion of a contingency allowance, estimates developed using the cost methodology would not meet the desired ±30% intent.

Response: The EPA disagrees that a 30% contingency for carbon adsorbers is appropriate. Carbon adsorbers are a mature and long-standing technology, and thus a 30% contingency is not reasonable for estimating the capital costs for such a device. The EPA has revisited its contingency estimates, however. In the revised Control Cost Manual methodology chapter, the contingency was increased from 3% of PEC (purchased equipment cost) to 5-15% of total capital investment (TCI) in response to public comments on the magnitude of the contingency and also a review of the available literature. After this review and consideration of public comments, the EPA concluded that this increase in contingency yields an estimate that is consistent with guidance from the American Association of Cost Engineering International (AACE) and well-recognized references on process engineering, such as Peters and Timmerhaus's Plant Design and Economics for Chemical Engineering (5th edition, 2002). This revised contingency estimate is appropriate for mature technologies such as adsorbers. The changes to the contingency factor are included in the revised Carbon Adsorbers chapter.

1.5.1 Fixed-Bed Systems

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter noted that Section 1.5.1.1 of the draft chapter depicts typical carbon costs to be $0.75 to $1.25 for virgin carbon and $0.50 to $0.75 for reactivated carbon (mid-1999 dollars). The commenter said that 1999 costs may not be valid today and current values should be included in the chapter. The commenter said the sentence should be corrected to specify that the quoted costs are in in units of $/lb. of carbon.

Response: The EPA has revised the cost data for activated carbon based on information collected from activated carbon suppliers in January 2018.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: In Section 1.5.1.3 of the draft chapter (Section 1.7.1.3 in the final chapter), the commenter noted that the formula for estimating the ratio of total adsorber equipment cost to the cost of the vessels and carbon based on the gas flow rate was derived from four data points obtained in 1989. Given the changes in design practices and equipment in the years since then, the commenter thought the information was unlikely to be still valid. The commenter recommended new vendor data for package units be obtained and a new regression analysis be performed. The commenter said that continuous systems now must have spare blowers and filters, since no adsorber outages for maintenance are allowed as they were in the 1980s.

The commenter said that this section should also recognize that not all costs are captured by the ratio, since it only included vendor supplied equipment. Facility provided equipment must be separately added. The commenter said that some instrumentation, steam supply (typically including a steam header extension with block valves, a pressure controller and a safety valve), desorbate handling facilities, and utilities such as nitrogen, instrument and utility air, utility water, fire water, cooling water, are supplied by the facility.

Response: The EPA thanks the commenter for their input and notes that the Agency attempted to collect more current data on both costs and technology advances through extensive searches of various information sources, including databases (e.g., the EPA's RACT/BACT/LAER Clearinghouse), construction permits, journal articles, vendor information, EPA documents, and conference presentations. However, the cost data we collected was not sufficient to allow us to develop new cost correlations. For this reason, we specifically solicited comment on cost correlations, factors, and equations and asked for input on how the capital and operating costs should be updated (see 81 FR 65353, July 21, 2017). We have received updated information on activated carbon and canister costs from vendors since the NODA was issued, and that data has been included in the chapter. Although we agree with the commenter's remarks regarding the age of the data for vessels and continuous systems and the problems associated with scaling the data to current costs, the cost correlations included in the Manual nevertheless represent the best data currently available to us for use in this chapter.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: In Section 1.5.1.4 of the draft chapter (renumbered as Section 1.7.1.4 in the final Chapter), the total capital investment (TCI) is estimated from the purchased cost derived in the previous section. To make that estimate, the total adsorber cost is multiplied by 1.18 to obtain a purchased equipment cost (PEC) and then by 1.61 to obtain the TCI. The TCI does not include site preparation and any building costs and provides a breakdown of the factors that are included in deriving the 1.18 and 1.61 multipliers. However, the commenter said that these estimates also do not include the significant facilities associated with handling the desorbate or supplying steam or other utilities. The commenter said that these additional costs should be added.

The commenter also said that factors of 1.30 of the PEC used for direct installation costs and the factor of 1.31 of PEC used for indirect costs underestimate the costs.

Response: Site preparation and building are listed as a cost in estimating the TCI; thus, a user should include these costs when estimating costs. There is no factor listed to calculate these costs since, as the chapter states, "these are site-specific costs that depend very little on the purchased equipment costs." (see page 1-25 in the final chapter). There are no capital costs included for desorbate storage and handling facilities, steam generation and supply or other utilities. The EPA has no information to support the inclusion of these facilities in our cost estimates. As for the direct installation costs and indirect costs factors, no information has been supplied to demonstrate the assertion that the factors used by the EPA underestimate the costs. We therefore believe these factors represent the best estimates currently available for use in this chapter.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter said that Sections 1.5.1.3 and 1.5.1.4 of the draft chapter (Sections 1.7.1.3 and 1.7.1.4 of the final chapter) are only applicable to packaged carbon adsorption units with steam regeneration. The commenter recommended the EPA clarify that for field erected units the cost estimates must be developed by directly estimating the required equipment and its associated costs.

Response: The EPA has clarified that costs as estimated in these sections are applicable only to packaged carbon adsorption units with steam regeneration. The EPA notes that direct estimation of purchased equipment costs and associated costs can certainly be done in place of the equations and data provided in the Control Cost Manual provided the different costs are fully documented and credible for use and review.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter disagreed with the statement in the third paragraph in Section 1.5.1.2, page 1-14 of the draft chapter (Section 1.7.1.2 in the final chapter), "Most commonly, adsorber vessels are cylindrical in shape and erected horizontally …" The commenter said this statement is no longer accurate and that most beds are vertical. The commenter suggested revising this section to address vertical beds and mention that beds can be horizontal and, in that case, carbon bed depth is limited to about 1/3 of the vessel volume.

Response: The EPA agrees with the commenter's remarks and has made the following changes to Section 1.7.1.2 of the final chapter:

"Most ~~commonly,~~ adsorber vessels are cylindrical in shape and **may be** erected **either vertically or** horizontally (as in Figure 1.1). **For horizontal ~~V~~vessels** ~~configured in this manner are generally subjected to the constraint that~~ the carbon volume occupies no more than 1/3 of the vessel volume [9][10]. It can be shown that this constraint limits the bed depth to no more than: . .."

1.5.2 Canister Systems

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052

Comment: Canister Adsorption Systems – Section 1.5.2 (renumbered as Section 1.7.2 in the final chapter).

The commenter noted that the cost information for canister carbon adsorption systems in Section 1.5.2 of the draft chapter is over 18 years old and is based on a single vendor. The commenter said that the cost information presented is inaccurate and recommended the EPA obtain updated cost information for the two principal elements of this emission control system.

Response: The EPA has updated the costs for carbon canisters based on new information provided by equipment suppliers in 2018.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Cost Estimating Discussion for Carbon Canisters.

The commenter said that the discussion on page 1-10 (in the draft chapter) of relative costs of a carbon adsorber system as a function of the carbon charge is based on data obtained in April 1986. The commenter said that practices and requirements have changed in the last 31 years and recommended current cost estimates be obtained and this paragraph be updated.

The commenter also thought it was unreasonable to assume carbon canister costs from 1999 are still valid. Carbon canister costs are unlikely to inflate with the construction cost index or general inflation. The commenter suggested that EPA obtain new information from Calgon or another vendor.

Response: The EPA has updated the costs for carbon canisters based on new information provided by equipment suppliers in 2018. Commenter: American Petroleum Institute (API)

DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter noted the following typographical error in Section 1.5.1.2 (Section 1.7.1.2 in the final chapter), Page 1-17, Table 1.2 of the draft chapter: the word "Montel" should be "Monel".

Response: The EPA has corrected the typographical error in the final chapter.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter disagreed with the suggested installation cost of 20% of the canister cost. The commenter said that the canister must be placed some distance from the vent (e.g., at grade), which means that hoses or piping, block valves, a backflow preventer and, depending on the configuration, a safety valve may be necessary. The commenter said that even these simple facilities require some time and effort to install. The commenter said that there are significant costs for transferring the canister(s) to the needed location and for removing them and shipping them back to the vendor. The commenter said that these costs should not be ignored. The commenter said that a blower may be necessary in some canister installations to overcome the carbon pressure drop. In those cases, the commenter said there will be appreciable costs for the blower and its associated electrical system.

Response: We believe the installation costs for typical sites are generally within 20% of the cost of the canisters. However, the EPA acknowledges that for some sites installation costs will be higher due to site-specific issues. We made the following changes to clarify that the estimated installation costs represent typical installations and may be higher depending on site-specific conditions.

"**For typical sites,** ~~T~~ **t**wenty percent of the sum of the canister(s) cost, freight charges, and applicable sales taxes ~~would cover this~~ **covers the** installation cost. **However, installation costs may be higher depending on site-specific conditions. For example, canister units retrofitted at congested sites may require additional duct work, blowers, and valves.**"

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Cost Estimating Discussion for Carbon Canisters.

The commenter said that the discussion on carbon canister systems should indicate that for smaller installations, two canisters in series is the typical canister system used today. The commenter said that the canister costs would be double. The commenter also said that for continuously operating canister systems, piping and valves to allow switching out one canister while operating through the other must be specified. Typically, when breakthrough is observed between the canisters, the commenter said that the second canister becomes the lead and a new or regenerated canister is added as the secondary one.

Response: The EPA agrees with the commenter and has added the following discussion on how canisters are typically used in series in smaller installations.

We have added the following text to the end of Section 1.2.2 in the final chapter:

"A single carbon canister may be used for emissions sources that operate intermittently or that can be shut down to allow replacement of a saturated carbon canister. However, most systems use two or more canisters, installed either in parallel or in series. Systems with canisters arranged in series are common. This design has two advantages: (1) any breakthrough that occurs in the first canister is controlled by the second canister; and (2) canisters can be replaced without disrupting the production process provided each canister is capable of controlling process emissions. … Although safer and more convenient, using two canisters in series is more expensive than systems using a single canister."

We added the following text to Section 1.7.2 in the final chapter:

> "The number and size of canisters can be adjusted to accommodate certain design specifications. For example, the number of canisters calculated using the approach outlined above must be doubled for systems where two canisters are used in series. Similarly, a system designed to minimize the frequency of canister replacement must select canisters with larger capacity than estimated using the approach outlined above."

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Cost Estimating Discussion for Carbon Canisters.

The commenter said that larger systems are commonly used (e.g., 2000 lb canisters) to minimize the need to changeout the smaller canisters. The commenter suggested these larger canisters be mentioned in the discussion.

Response: The EPA agrees with the commenter and has included additional clarification in the Section 1.7.2 of the final chapter (see the response the previous comment). We have also added cost information for large canisters including 1,000 lb, 2,000 lb, 3,000 lb, 4,100 lb, 5,000 lb and 10,000 lb canisters (See Section 1.7.2 of the final chapter).

1.6 Estimating Total Annual Cost

1.6.1 Direct Annual Costs

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The commenter said that the annual operating cost estimate failed to include operator and maintenance labor. The commenter said once per shift samples of the canister outlets are typically required (0.5 operator hours per day) and that 4 to 8 hours of maintenance labor is required for each canister replacement.

Response: The EPA agrees with the commenter that operator labor and maintenance labor should be included in the total annual cost for operating larger canister-type adsorbers. The following changes were made to Section 1.81 in the final chapter in response to this comment:

"Direct annual costs include the following expenditures: steam, cooling water, electricity, carbon replacement, operating and supervisor labor, and maintenance labor and materials. Of these, only **operator/supervisor labor, maintenance and materials labor,** electricity and solid waste disposal or carbon replacement/regeneration ~~would~~ apply to the canister-type adsorbers."

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: The Cost Manual bases carbon-related capital and operating costs on an assumed carbon life of five years. However, the commenter noted that for some facilities, the basis for replacing carbon or for sending carbon offsite for regeneration is one year. The commenter recommended changing the basis for the calculations to annual.

Response: The EPA thanks the commenter for their input and has revised Section 1.8.1.4 (Carbon Replacement) of the final chapter as follows:

> "A typical life for the carbon is five years. However, if the inlet contains VOCs that are very difficult to desorb, tend to polymerize, or react with other constituents, a shorter carbon lifetime~~— perhaps as low as~~ **of one or** two years **is**~~— would be~~ likely.[1]"

We have not revised the example problem in Section 1.9 of the final chapter as the example is provided for illustration purposes only and is consistent with the carbon life typically observed for carbon adsorbers used in many industries.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Annual Cost Estimating Discussion for Carbon Adsorbers.

In response to the last paragraph of Section 1.6.1.5 of the draft chapter (Section 1.8.1.5 in the final chapter), the commenter said that the costs for canister disposal are from 1986 references. The commenter recommended updated costs be obtained and that handling and shipping cost be added to the disposal cost. Furthermore, the commenter noted that canisters from petroleum refining or chemical sources are likely to contain benzene and be subject to the requirements in the Benzene Waste Operations NESHAP and therefore, disposal at landfills is not permitted. The commenter said that the carbon contaminated with benzene must be incinerated. The commenter said that incineration is more expensive and said the discussion in the chapter should identify this common alternative disposal and provide an estimated cost.

Response: The EPA thanks the commenter for their input and notes that the Agency attempted to collect more current data on canister disposal through extensive searches of various information sources, including databases (e.g., the EPA's RACT/BACT/LAER Clearinghouse), construction permits, journal articles, vendor information, EPA documents, and conference presentations. However, the cost data we collected was not sufficient to allow us to develop updated costs. For this reason, we specifically solicited comment on how the capital and operating costs should be updated (see 81 FR 65353, July 21, 2017). We have received updated information on activated carbon and canister costs from vendors since the NODA was issued, and that data has been included in the chapter, but not canister disposal. However, we have added additional context to the discussion of canister disposal in the final chapter.

1.6.2 Indirect Annual Costs

Commenter: American Fuel and Petrochemical Manufacturers (AFPM)
DCN: EPA-HQ-OAR-2015-0341-0052

Comment: Equipment Life

The commenter said that establishing a reasonable estimate of equipment life is difficult for the hardware associated with carbon adsorption systems because equipment life varies depending on system operating conditions. The commenter noted that systems that handle waste gases containing chlorinated hydrocarbons have relatively shorter operational lives than other systems. The commenter agreed with the EPA's assessment that a five-year operational life estimate for carbon is reasonable; however, the commenter said that the 10-year life for the adsorber hardware (vessels, pumps, etc.) appears to be low. The commenter said that adsorption systems typically have operational lifetimes of 15 to 25 years. The commenter encouraged the EPA to conduct research among adsorption system equipment vendors to obtain the most technically supportable information about the range of expected equipment life and the factors that influence it.

Response: The EPA agrees with the commenter that equipment life varies depending on the system operating conditions. We also agree that systems handling more corrosive waste streams, such as waste streams containing chlorinated hydrocarbons, will have shorter equipment life than those handling more benign wastes streams. In response to the commenter's remarks regarding the typical equipment life for carbon adsorption systems, the EPA has added the following text to Section 1 of the final chapter:

> "Typical equipment life for carbon adsorbers is between 15 and 25 years. However, systems that handle waste gases that contain corrosive materials, such as hydrogen chloride or other acid gases, have shorter equipment life due to the impact of corrosion on the adsorber components. For example, waste streams that contain corrosive gases can corrode the adsorber vessel walls, carbon bed supports and outlet ducts. Corrosion of the bottom of the adsorber vessel is common where components of the gas stream condense to form corrosive liquids that collect on the bottom of the vessel. Corrosion of the carbon bed supports is also possible and may eventually cause the carbon beds to collapse. Carbon adsorbers used to control gas streams that contain corrosive materials should be constructed of materials that are designed for and resistant to corrosion."

The following revisions were made to Section 1.8.2 of the final chapter:

> "For adsorbers, the ~~system~~ **equipment** lifetime is typically **15 and 25** ~~ten~~ years, except for the carbon, which, as stated above, typically needs to be replaced after five years."

The EPA has also updated the example in Section 1.9 of the final chapter to reflect a 15-year equipment life and a 5% interest rate. Specifically, the calculations shown in Section 1.9.3 and Table 1.8 were revised. Footnote (b) in Table 1.8 was updated as follows:

> "(b) The capital recovery cost factor, CRF, is a function of the carbon or equipment life and the opportunity cost of the capital (i.e., interest rate). The CRF is calculated using the following equation: $i(1+i)^n/((1+i)^n-1)$, where n is equipment life and i is the interest rate. For a 5-year carbon life and ~~7~~ **5**% interest rate, the CRF is 0.**23102**~~2439~~. For a **15**~~10~~ year equipment life (adsorber vessel and auxiliary equipment) and a ~~7~~**5**% interest rate, the CRF = 0.**0.0963**~~1424~~."

1.6.3 Recovery Credits

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: In Section 1.6 of the draft chapter, the commenter disagreed with the discussion of the total annual operating cost for a fixed-bed carbon system because it does not address the "appreciable costs associated with recovering or discarding the desorbed hydrocarbon." The commenter recommended that the section be revised to include information for estimating the annual cost for disposing of the desorbed hydrocarbon and the associated water and for separating the hydrocarbons from the water condensate.

In Section 1.6.3 of the draft chapter (Section 1.8.3 in the final chapter), the commenter said that the cost of recovering the hydrocarbon from the desorbate is often more than the value of the recovered material. The commenter disagreed with the suggestion that the recovered VOC can be burned as fuel. The commenter said this was not typically a viable alternative. They noted that the VOC must be separated from the water phase and said that burning is often prohibited under consent decrees in the petroleum and petrochemical industries. The commenter said that the recovered material may be sent to a fuels recovery vendor or, if required because of the benzene content, to an incinerator. In both cases, the commenter noted that a cost would be incurred. The commenter recommended that this cost should be reflected in the discussion. The commenter said that there would also be investments involved for storing and then loading the desorbate for shipment.

The commenter also noted that the example in Section 1.7 of the draft chapter (Section 1.9 in the final chapter) is atypical for refineries and similar industries, where the VOCs are typically a mixture of many hydrocarbons, often including significant percentages of benzene. The commenter said that recovery for fuel or at best feedstock value are the only viable recovery options and, for smaller quantities that contain toxics, having the material incinerated is just as likely. The commenter recommended the EPA emphasize in the example that having a single component VOC is unusual and mixtures will have much lower recovery values and may instead incur a cost for having the material incinerated or reprocessed.

Response: The EPA agrees with the commenter that many industrial waste streams are comprised of mixtures of VOCs and/or HAP that may be difficult or uneconomic to separate and consequently have little or no resale value. We also agree that in some situations the facility may incur disposal costs. To clarify that costs of disposal should be included for those situations where the collected material cannot be re-used onsite or sold to recyclers, we changed the title from "Recovery Credits" to "Recovery Credits and Disposal Costs" and made the following revisions to the subsection 1.8.3 in the final chapter:

"~~These apply to the~~ **During the desorption cycle,** VOC ~~which~~ ~~is adsorbed, then~~ **is** desorbed, condensed, and separated from the steam condensate. **The recovered VOC can be re-used on site (e.g., as a solvent or burned as a fuel), sold to recyclers, or sent to a disposal site.** If the recovered VOC is sufficiently pure, it can be **reused onsite** or sold. **As the example problem in Section 1.9 illustrates, if the quantity of recovered VOC is large enough, its value can offset the annual costs of the control device, resulting in a net annual credit. However, the current market price of the VOC and its purity impact the size of the credit. The greater the purity, the higher the value.** However, if the **recovered** VOC contains impurities or is a mixture of compounds, ~~it would require~~ further treatment, such as distillation**, will be required**. Purification and separation costs are beyond the scope of this chapter. Needless to say, the costs of these operations **can be significant and should be included in estimates of the capital and operating costs and** ~~would~~ offset the revenues generated by the sale of the VOC. ~~Finally, as an alternative to reselling it, the VOC could be burned as fuel and valued accordingly.~~ **Where the facility is unable to re-use or sell the waste VOC collected, the facility may incur costs associated with its off-site disposal.**"

Recovery Credits:

The following equation can be used to calculate these credits:

$$RC = m_{voc}\ \theta_s\ p_{voc}\ E \qquad (1.40\mathbf{a})$$

. . ."

Disposal Costs:

In situations where the collected VOC must be sent off-site for disposal, the following equation should be used to calculate the disposal costs:

$$Disposal_{Cost} = m_{voc}\ \theta_s\ D_{voc}\ E \qquad \mathbf{(1.40b)}$$

where

$Disposal_{Cost}$	=	**Disposal cost ($/yr)**
m_{voc}	=	**VOC inlet loading (lbs/h)**
θ_s	=	**system operating hours (h/yr)**
D_{voc}	=	**disposal costs for the recovered VOC ($/lb)**
E	=	**adsorber VOC control efficiency**"

Section 1.9.2 (Total Annual Costs) in the final chapter was updated as follows:

"As discussed in section 1.~~6~~**8.4**, the total annual cost (TAC) is comprised of the direct annual costs (DAC), indirect annual costs (IAC), **annual disposal costs (*Disposal$_{Cost}$*)** and any recovery credits (RC), as described by the equation:

TAC = DAC + IAC + Disposal$_{Cost}$ – RC

The following changes were made to Section 1.8.4 of the final chapter:

"Finally, as explained in Section 1.68, the total annual cost (TAC) is the sum of the direct annual costs, and indirect annual costs and disposal cost, less any recovery credits, or:

(1.41)

where

DAC = Direct annual costs,

IAC = Indirect annual costs,

Disposalcost = Costs for disposing or otherwise treating recovered VOC,

and

RC = Recovery credit.

. . .

Recovery Credit: In this example, we have included a credit for the recovery and re-sale of toluene. The quantity of toluene recovered is estimated from the toluene emission rate (100 lb/hour), the number of operating hours (8,640 hours/year), and the control efficiency of the carbon adsorber (98%).

Equation 1.39 is used to calculate the recovery credit:

$$RC = m_{voc}\,\theta_s\,p_{voc}\,E = \left(\frac{100lbs}{hr}\right)(8640hrs)\left(\frac{\$0.33}{lb}\right)(0.98) = \$279{,}000$$

Hence, a recovery credit of $279,000 can be taken for the recovery and re-sale of 423 tons of recovered toluene. Since all of the toluene can be recovered and sold, no disposal costs will be incurred. Hence, for this example, the *Disposal$_{Cost}$* equals zero.

Total Annual Cost: The sum of the direct **annual costs,** ~~and~~ indirect annual costs **and annual disposal costs**, less the toluene recovery credit, yields a net total annual credit of **$60,400**. Clearly, total annual cost is very sensitive to the **amount and** ~~recovery credit and the~~ value of the recovered toluene. For instance, if the ~~full~~ market price for toluene was **$0.15/lb** ~~of $607/ton~~**, then the recovery credit would be $127,000** ~~is used to calculate the recovery credit,~~ **and** the total annual cost would be **$92,000** ~~$80,900~~. Thus, when incorporating recovery credits, it is imperative to select the value of the recovered product carefully."

1.6.4 Total Annual Cost

No comments received.

1.7 Example Problem

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Fixed Bed, Steam Regeneration, Example in Section 1.7 of the draft chapter.

The commenter disagreed with the example because the system had two adsorbing beds in parallel and the carbon charge in each bed as only 50% of the amount needed to handle 12 hours of treatment. The commenter said that this arrangement may be suitable for handling intermittent steams that can be interrupted if necessary (e.g., due to the outlet approaching the regulatory limit), but would not be suitable for continuous streams since it would be a CAA violation to continue to operate if breakthrough occurs, even if due to a malfunction. The commenter said that the Cost Manual should reflect the EPA's revised malfunction policy. The example should consist of two 100% beds. When the outlet concentration of the adsorbing bed approaches breakthrough, it would be taken out of service and put on regeneration and the standby regenerated bed would be put into adsorption service. Each bed would have to be sized to allow full compliance for the period required to regenerate the other bed, plus some spare to allow for regeneration delays or unusually high feed concentrations.

Response: The method used to estimate the quantity of carbon calculates the total carbon required for all three adsorber vessels (M_c), including the quantity of carbon in the vessel being regenerated when the other two vessels are adsorbing. In the example, the total amount of carbon required is divided between the three adsorber vessels, such that two vessels must be operating at any one time in order to effectively control the VOC emissions. The commenter is correct that changes to the startup, shutdown and malfunction rules require the source be in compliance with emission limits during malfunction events. If one of the adsorber vessels fails, the operator would have to take actions to ensure the emissions limits are met. The facility could install an adsorber system with additional capacity, as suggested by the commenter. However, increasing the capacity of the adsorber system is not the only approach a facility can take. For example, a facility may choose to temporarily shut down the emission source or re-rout the emissions to another control device.

Commenter: American Petroleum Institute (API)
DCN: EPA-HQ-OAR-2015-0341-0050

Comment: Comments on the Fixed Bed, Steam Regeneration, Example in Section 1.7 of the draft chapter (Section 1.9 in the final chapter).

Regarding Table 1.3 of the draft chapter, the commenter said that the major equipment cost (carbon adsorber package, including the initial carbon charge) was multiplied by 1.18 to calculate the PEC, which is the basis for estimating the TCI. Of the 18% increment, 10% is for instrumentation, 3% for sales tax and 5% for freight. The commenter said that the example includes no costs for instrumentation and assumes the instrumentation is included in the PEC. The commenter disagreed with this estimate because they said the vendor supplied instrumentation must have power, instrument air, and be connected to central systems to provide alarms and the records required for demonstrating continuous compliance and for QA/QC of the instruments. The commenter said that the 10% allowance may be adequate to cover these additional costs, but would not cover the instruments that are not typically provided in the purchased package (e.g., vent gas and steam flow, temperature and pressure) and instrumentation that was not typical in a 1986 carbon adsorber system, or the continuous breakthrough monitoring that is required by various rules. For example, the BWON rule requires either 1) a monitoring device equipped with a continuous recorder to measure either the concentration level of the organic compounds or the benzene concentration level in the exhaust vent stream, or 2) a monitoring device equipped with a continuous recorder to measure a parameter that indicates the carbon bed is regenerated on a regular, predetermined time cycle. Subpart SS, used by Ethylene MACT and the MON, and the HON require 1) an organic monitoring device capable of providing a continuous record, or 2) an integrating regeneration stream flow monitoring device having an accuracy of ±10 percent or better, capable of recording the total regeneration stream mass or volumetric flow for each regeneration cycle; and a carbon bed temperature monitoring device, capable of recording the carbon bed temperature after each regeneration and within 15 minutes of completing any cooling cycle.

Some of this instrumentation, the commenter said, would be captured if the auxiliary equipment ratio in Section 1.5.1.3 of the draft chapter is updated for current design practices. However, the commenter said that the facility-provided instrumentation and breakthrough monitors provided by third parties would still not be included and would have to be separately estimated and added to the cost.

Response: The EPA thanks the commenter for their input and note that the Agency attempted to collect more current data on instrumentation and breakthrough monitors through extensive searches of various information sources, including databases (e.g., the EPA’s RACT/BACT/LAER Clearinghouse), construction permits, BACT permits, journal articles, vendor information, EPA documents, and conference presentations. However, the cost data we collected was not sufficient to allow us to develop new or additional cost estimates including these items. We specifically solicited input on how the capital and operating costs should be updated (see 81 FR 65353, July 21, 2017). After review of the comment, we believe the cost estimates for these items we have in our chapter nevertheless represent the best data currently available to us for this chapter.