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Project Summary

Full-Scale Carbon Adsorption Applications Study

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The full report presents the results of theoretical and field test investigations of full-scale carbon adsorption applications. The program focused on the performance testing of several fixed-bed, steam-regenerated carbon adsorption systems used in the rubberized fabric, magnetic tape, and flexible packaging industries. The test results showed that a 95 percent volatile organic compound (VOC) reduction can be expected for most common industrial solvents when exhaust gases are processed through a properly designed and operated activated carbon bed. The test program was also designed to measure the effective carbon life for each of the test facilities. Carbon life was found to vary from plant to plant and ranged from as low as 9 months at a magnetic tape facility to over 5 years at a rubberized fabric coating operation. The full report also includes a brief discussion on the theory of carbon adsorption and on computer simulations of carbon bed systems.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The U.S. Environmental Protection Agency (EPA) is currently evaluating the environmental and health impacts of volatile organic compound (VOC) emissions from a variety of industrial sources. As part of this effort, Radian Corporation has contracted a program (EPA Contract No. 68-03-3038) to evaluate the performance of full-scale vapor-phase carbon adsorption VOC control systems for solvent recovery. Inherent in any cost-effectiveness evaluation of a carbon adsorber installation is some decision on the effective life of the carbon. The Agency was unable to find substantive data to reflect the effect of irreversible fouling that may take place as a result of impurities or byproducts of some industrial operations. This study was initiated to investigate the change, if any, in efficiency of the carbon bed with time.

Carbon adsorption-based solvent recovery is a commonly used VOC control technology in the surface coating industry. Economic and/or regulatory incentives contribute to its wide application. Limited data are available on measurements of carbon service life and VOC removal efficiencies for full-scale, existing carbon bed systems. Therefore, to evaluate the VOC control performance, the following program objectives were established: (1) to determine the effects of carbon service life on long-term system performance and (2) to compare the performance of the tested systems and the major factors affecting performance.

Summary of Results

Six full-scale activated carbon systems were tested at various locations across the United States. The test sites included two plants from each of the following surface coating industries: rubberized fabric, magnetic tape, and flexible packaging. These categories were selected because they represented a variety of coating solvents and control system sizes. The coating solvents examined in the study include hexane, toluene, tetrahydrofuran (THF), isopropyl acetate, n-propyl

acetate, and methyl ethyl ketone (MEK). The volumetric flow rate of the gas streams treated ranged from 3.7 to 32 Nm^3/sec (7800 to 68,000 scfm). The adsorption systems at the rubberized fabric and flexible packaging plants feature horizontal carbon beds, although SLA flow direction through the beds differs (downward for the rubberized fabric plants and upward for the flexible packaging plants). Conversely, the magnetic tape plants feature adsorption systems with annular carbon beds, although again, SLA flow direction through the bed differs (inward for one plant and outward for the other). The number of carbon beds per system also varied from two to six, depending on the volume of gas being treated.

The relative SLA flow rates, as compared to the bed carbon capacity, average approximately 0.0015 Nm^3/sec-kg carbon (1.5 scfm/lb carbon) for the six tested systems with the rates ranging from a relatively conservative 0.00069 Nm^3/sec-kg carbon (0.65 scfm/lb carbon) to a high of 0.0026 Nm^3/sec-kg carbon (2.5 scfm/1b carbon). Also, the horizontal bed systems generally feature average design superficial bed velocities of 0.45 m/sec (89 fpm), while the thin-bed designs of the annular bed systems feature lower velocities, nominally 0.33 m/sec (65 fpm). The six designs are characterized by significant differences in inlet solvent loadings, with average inlet concentrations ranging from less than 1000 ppmv to over 4000 ppmv. On a carbon basis, design solvent loadings vary over an order of magnitude, from 0.0066 to 0.097 kg solvent/kg carbon (0.0066 to 0.097 lb solvent /lb carbon).

Cost data were also developed for each of the tested facilities based on plant information. In 1983 dollars, the total capital costs for the activated carbon systems range from $267,000 to $2,685,000. The capital cost normalized to the SLA flow rate ranges from $51,000 to $173,000 per Nm^3 ($24 to $82 per scfm). The normalized annual costs range from 0.19 to 0.66 $/kg (0.09 to 0.30 $/lb) of recovered solvent.

The carbon adsorption systems were tested using EPA and ASTM methods. Inlet and outlet VOC concentrations were measured semicontinuously with flame ionization detector (FID) total hydrocarbon (THC) instrumentation as described in EPA Method 25A. Volumetric flow rates were measured according to EPA Methods 1 and 2. All test results were verified by EPA-specified quality assurance/quality control procedures. Other process information, including steam rate, steam temperature, SLA temperature, and carbon weight, was determined from process instrumentation or design specifications.

All six plants were originally tested in early 1982. During these tests, data were taken to characterize the VOC removal efficiency of the carbon bed systems and to characterize the conditions of the carbon. Four of the six plants were retested using the same test methods approximately 18 to 22 months later. A comparison of the changes in performance was made in an attempt to define the effects of long-term carbon degradation. In general, the data indicate significant differences in performance from plant to plant and from test period to test period. However, these differences were not always attributable to carbon degradation. A summary of the test results for all six plants is shown in Table 1.

The average VOC control efficiency data indicate that, with the exception of one plant, all tested adsorption systems were capable of achieving efficiencies of 95 percent or greater. (Mechanical problems at two plants caused considerable decreases in the VOC control performance during the repeat testing.) Average removal efficiencies exceeding 99 percent were measured for two of the systems during the original testing.

The useful carbon life of the activated carbon systems examined in this study ranged from a few months to over 6 years. During the repeat testing at four of the original six test sites, carbon degradation was definitely detected at only one of the facilities. The other three facilities either did not indicate any substantial reductions in VOC removal performance or were experiencing reductions in performance not related to carbon degradation. It was concluded that the test methods currently used for measuring carbon bed performance cannot be used to predict useful carbon life.

Table 1. Comparison of Test Results—Plants 1-6

	Rubberized Fabric			Magnetic Tape			Flexible Packaging			
PLANT	1	5		2		3	4		6	
	Original Test	Original Test	Repeat Test	Original Test	Repeat Test	Original Test	Original Test	Repeat Test	Original Test	Repeat Test
Solvent Type	MEK	toluene	toluene	THF/toluene[a]	THF/toluene[a]	THF/toluene/ MEK/MIBK/ cyclohexanone	hexane	hexane	toluene/IPAC	toluene/IPAC
Adsorption mode length, min	95[b]	150	200	64	65	47	120	90	470[b]	560[b]
SLA flow rate, Nm^3/sec (scfm)	5.4 (11,400)	4.3 (9,100)	3.7 (7,800)	4.6 (9,800)	4.5 (9,500)	9.4[c] (19,800)	8.3 (17,700)	10.7 (22,600)	15.8[d] (33,400)	16.0[d] (33,900)
Inlet solvent concentration, ppmv	2,190	1,940	896	1,470	1,140	3,220	1,260[e]	940[e]	904	847
VOC control efficiency, %	84.9	97.6	80.5	99.7	95.2	94.7	99.0[e]	46.7[e,f]	97.5	97.9
Desorption mode length, min	55	50	40	32	32	35	25	25	30	30
Steam/recovered solvent, kg/kg (lb/lb)	20 (20)	8.2 (8.2)	15 (15)	5.2 (5.2)	6.5 (6.5)	6.0 (6.0)	4.6 (4.6)	11 (11)	1.0 (1.0)	0.8 (0.8)
Carbon age, years	0.4	5.0	6.5	2.0	3.8	0.4	3.0	4.5	0.2	1.6
Cost Information (1983 dollars)										
Total Capital, 10^3	622	267		650		1,800	1,334		2,685	
Relative Capital, $10^3/Nm^3/sec$ ($/scfm)	110 (56)	51 (24)		108 (51)		173 (82)	129 (61)		72 (34)	
Total Annualized Cost, 10^3	262	125		325		1,430	494		839	
Relative Annualized Cost, $/kg Recovered solvent ($/lb)	0.53 (0.24)	0.19 (0.09)		0.61 (0.28)		0.66 (0.30)	0.51 (0.23)		0.28 (0.13)	

[a] Original THF/toluene percentages were 50/50; repeat test percentages were 75/25.
[b] Cycle timing controlled by exhaust gas (breakthrough) hydrocarbon analyzer.
[c] Flow rate measured when 4 of the 6 beds were in service (2 beds were on permanent standby).
[d] Process Train 1 conditions (total system capacity was twice that of Process Train 1).
[e] Measurements made at common inlet/common outlet.
[f] Removal efficiency is low due to steam valve leakage (99 percent efficiency was measured after repair of the valves).

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***Ronald J. Turner** is the EPA Project Officer (see below).*
The complete report, entitled "Full-Scale Carbon Adsorption Applications Study," (Order No. PB 85-172 906/AS; Cost $20.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
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